Exploring Pedestrian Counting Procedures

A Review and Compilation of Existing Procedures, Good Practices, and Recommendations

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16. Abstract Clear and comprehensive information about pedestrian travel patterns is critical to multimodal transportation planning, programming, and management. This report covers existing guidance and best practices to recommend strategies for accurate, timely, and feasible measurement of pedestrian travel. Recommendations include: 1) expand the use of multi-day/multi-week counts to reduce estimation error rates, and rotate counts around the network; 2) validate equipment at installation and regularly thereafter; 3) tailor quality checks appropriate for low volume versus high volume locations; 4) compute bias compensation factors (e.g., occlusion adjustment factors) to account for limitations related to equipment and locations; and 5) conduct both short-duration and continuous counts to fully consider temporal and spatial aspects of pedestrian traffic patterns.		
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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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1. INTRODUCTION

Clear and comprehensive information about pedestrian travel patterns is a critical component of multimodal transportation planning, programming, and management. Sound data on pedestrian system usage is needed by a wide variety of practitioners, including state and local agency staff responsible for traffic safety, operations, maintenance, planning, design, and construction, as well as system user outreach and education. Pedestrian travel has unique characteristics that affect the design and operation of data collection systems and analyses related to pedestrian facility usage and safety issues. Because of the unique characteristics of pedestrian travel, pedestrian counts require a distinct, valid, and replicable methodology that enables transportation agencies to assess pedestrian travel trends and needs on par with the established existing methods for monitoring motor vehicle travel.

The practice of monitoring motor traffic volumes has been a routine task for State Departments of Transportation (DOTs) since the 1950s. A federal mandate issued in 1997[1] spurred the development of DOT-operated traffic monitoring programs across the country. These programs have provided the transportation community, unified and consistent approaches in collecting and processing traffic data and the monthly motorized traffic volume data to Federal Highway Administration (FHWA). DOT staff from all states routinely avail themselves of relevant federally-sponsored training programs and resources, such as the FHWA Traffic Monitoring Guide (TMG), which provide ample information to support development and operation of vehicle traffic monitoring systems.

While motorized traffic monitoring systems are now ubiquitous across the nation, most transportation agencies do not collect data on nonmotorized traffic trends. The state of the practice has been defined by a relatively small group of DOTs and local transportation agencies that have chosen to take on the task of counting nonmotorized traffic, including pedestrians, for a variety of purposes, such as the following:

- Designing and operating multimodal roadways
- Conducting pedestrian studies
- Developing multimodal transportation plans, including travel demand modeling
- Supporting economic development, such as real estate assessment and marketing
- Making policy and investment decisions that rely upon performance measures, such as project funding assessment and prioritization

Each purpose involves specific data needs and requirements. For example, data on the number of pedestrian crossings at intersections are needed for signal timing and safety studies, but data on total pedestrians traveling through intersections may better support policy decisions. The pedestrian monitoring programs developed by these leading agencies were designed around individual needs and resources, and collectively do not represent a replicable, valid methodology than can be applied nationally. A national approach to pedestrian data collection includes standardization to the extent possible while acknowledging the unique data needs for different purposes.

Recognizing the importance of providing guidance on the collection of nonmotorized counts, FHWA updated the TMG in 2013 to include a new chapter on counting nonmotorized traffic. The new edition includes information on counting pedestrians, bicyclists, and other nonmotorized road and trail users. Even though both of these modes preceded the automobile, the counting of nonmotorized traffic has not been systematic or widespread in the U.S. and, even today, is not nearly as comprehensive as motorized traffic monitoring.

This report reviews, analyzes the issue, and provides a potential resource for moving toward the creation of a nationally applicable pedestrian counting methodology by combing existing guidance and best practices in order to identify key issues and recommend creative strategies for developing accurate, timely, and feasible approaches for measuring pedestrian travel. By incorporating findings from this project and related initiatives into national traffic monitoring training programs and resources, jurisdictions may advance the state of the transportation planning and design practice to support multimodal analyses that can help planners and engineers to identify strategic pedestrian investments that will improve safe, efficient multimodal accessibility for Americans of all ages, abilities, and economic levels.

KEY TERMS

This report discusses several aspects of pedestrian traffic counting elements, including:

- Technology: Automated and manual counting methods
- Duration: Short-duration and continuous counts
- Facility types: Intersection and segment counts

For the purposes of this report, we use the following definitions for the above terms:

Automated counts refer to counts collected by machine, including automated counts from video using video-image recognition software. *Manual* counts are those collected by a human being either in person at the site or by watching video of the site later.

Short-duration counts include counts less than 24-hours in duration, often collected manually, and *Mid-term* counts collected by mobile automated equipment for multi-day or multi-week time periods.

Continuous counts are automated counts collected 24 hours a day, 365 days a year at permanent count stations over at least a one-year period.

Intersections refer to any road or path junction, including roundabouts and traffic circles. *Segments* are road or path segments between intersections. We use the term “segment” instead of the term “screenline,” which is used in the TMG, to avoid confusion with the alternative definition of “screenline” commonly applied to cordon counts around a city or region.

STRUCTURE OF THIS REPORT

This report is organized into six main sections, as described below.

- The introductory section describes the genesis, purpose, and organization of the report.
- Section two reviews the current state of the practice based upon a review of academic literature, information volunteered by participants in a national webinar, and insights from interviews with leaders in the field of pedestrian counting.
- Section three focuses on available data collection technologies and procedures for deploying pedestrian traffic counting equipment, from budget allocation and purchasing to installation.
- Section four describes the process of planning and designing a pedestrian counting program, including details such as establishing appropriate count durations and frequency.
- Section five discusses data management issues, including quality checking, metadata, data sharing, and analysis.

- Section six summarizes key findings from the each chapter that are particularly relevant for practitioners to consider when developing and enhancing pedestrian counting programs.

Sections 2 through 5 each begin with an introduction, followed by insights from reviews of literature and other resources, and a concluding summary of findings and recommendations.

2. CURRENT PRACTICE

INTRODUCTION

Over the last decade, there has been increased emphasis on no motorized travel at the national as well as local level. As a result, agencies are investing in the collection and storage of nonmotorized count data. These count data are critical for conducting safety analyses, monitoring trends, prioritizing projects, predicting future demands on a facility, planning and infrastructure design, and calibrating and validating travel demand models.

While motorized travel counting methods and data collection technologies are well established, methods and technologies to collect nonmotorized data are fairly new and have been continuously evolving over the last few years. In 2014, the Transportation Research Board (TRB) bicycle and pedestrian data subcommittee published a research circular that detailed the state of research and practice with respect to nonmotorized travel and behavior.[2] In the same year, the National Highway Cooperative Research Program (NCHRP) Report 797 Guidebook on Pedestrian and Bicycle Volume Data Collection and companion Web-only Document 205, provided a comprehensive overview of methods and technologies for collecting bicycle and pedestrian data and guidance for agencies seeking to establish count programs.[3]

The purpose of this chapter is to review existing academic literature on the various elements associated with nonmotorized counting programs as well as to document insights from practitioners. Practitioner input was solicited through two means: a nationally distributed webinar open to all interested staff and members of the public, and individual telephone interviews with a small representative sample of transportation professionals. This chapter is organized in the following manner: a review of the academic literature, a summary of input from the webinar and interviews, and key findings.

LITERATURE REVIEW

The project team conducted an academic literature search to identify literary sources for pedestrian travel counting using the TRB TRID database to conduct the search. In addition to TRID, we drew on sources identified in the TMG, NCHRP Report 797 Guidebook on Pedestrian and Bicycle Volume Data Collection, the TRB Bicycle and Pedestrian Data Subcommittee's 2014 research circular, and a 2011 report on pedestrian and bicycle data collection by AMEC E&I Inc. and Sprinkle Consulting[4]. The academic literature search revealed studies in the following areas: Counting Programs, Count Duration and Timing, Count Site Selection, Technologies and Managing Count Data. Each of these is described further below. The Appendix contains summaries of the relevant studies in each category.

Counting Programs

There are a number of elements associated with planning and implementing nonmotorized data collection programs. NCHRP 797 outlines the following steps necessary to establish a counting program.

Planning a Count Program

Planning a count program is a critical step prior to implementation. Steps involved in planning a count program are as follows:

- **Defining purpose** – A clearly defined purpose statement guides decisions such as when, where and how to conduct counts.

- **Identifying resources** – The available resources will determine the scale of the counting program.
- **Select locations and time frame** – The choice of locations and time frame is determined by whether the counting program includes short-duration counts, continuous counts, or both.
- **Select counting methods and technologies** – The selection of counting methods and technologies depends on physical and user characteristics of the site and on the types of data required.

Implementing a Count Program

NCHRP 797 outlines the following steps for implementing a continuous counting program.

- **Obtaining Permission –** Permission is often required from landowners or rights-of-way owners prior to counter installation; the time required to obtain permission from all relevant parties should be factored into the schedule.
- **Procuring Counting Devices** – Prior to implementation, procuring count devices is essential. The procurement process is influenced by agency requirements and specifications for vendors and equipment.
- **Inventorying and Preparing Devices** – Maintaining an equipment inventory is useful in tracking multiple pieces and locations of equipment.
- **Training Staff** – Staff may need to be trained for both automated equipment and manual counting.
- **Installing and Validating Count Data** – Care should be taken to ensure that the counters are installed and working properly. Validation is an important step in the setup process. Data from the counters should be carefully validated on multiple days.
- **Calibrating Devices** – The devices should be adjusted for sensitivity based on whether any readings of missed counts or false counts were obtained. This is an iterative process.
- **Maintaining devices** – The installed devices should be checked periodically to ensure that they are in good working order and producing good data.
- **Managing Count Data** – Count data can be managed either in-house or by a vendor using custom software. Where possible, leverage the motorized count database to also include nonmotorized data.
- **Cleaning and Correcting Data** – Appropriate quality assurance and quality checks should be performed prior to using the data for analysis. Correction factors can be used to adjust over or under counting.
- **Applying Count Data** – Once the data have been cleaned and corrected, they can be used for evaluating performance measures.

Counting Programs – Findings

Although there is a growing consensus on the importance of collecting nonmotorized data, only a few states have started to institutionalize data collection procedures and policies, drawing upon limited existing guidance. The lack of widespread count programs is often due to a combination of lack of resources, lack of guidance, and perceived need and program and project priority.

The first effort to design a nationwide counting program, undertaken by Alta Planning and Design and the Institute of Transportation Engineers in 2004, was titled the National Bicycle and Pedestrian Demonstration Project (NBPDP)[5]. Since then a few states, as well as some cities and counties, have established both continuous and short-duration count programs. The Appendix provides a table of relevant literature and key takeaways from research on these efforts; the following paragraphs highlight key findings.

Baker et al. reviewed various state counting programs.[6] Their 2012 review revealed that 16 states had established bicycle and pedestrian programs with some travel monitoring, 18 states had programs but did not perform any counting, and 16 states had no programs and did not conduct any nonmotorized counting. Baker et al. identified the states of Colorado, Vermont and Washington as leaders with respect to counting nonmotorized traffic, but did not provide specific detail on the type and extent of pedestrian counting programs. In a related study, Lindsey et al. outlined the progress made by Colorado, Oregon and Minnesota in establishing counting programs and suggested more research to determine the appropriate number of locations for continuous and short-duration counts necessary to characterize flows on a network, as well as the resources needed to institutionalize such programs.[7] Minge et al. also provided recommendations for setting up a count program in Minnesota[8].

Schneider et al. performed case studies of 29 communities engaged in nonmotorized data collection.[9] The communities studied use nonmotorized data to determine trends in activity, safety and facility usage; estimate peak hour and temporal adjustment factors; identify locations for facility improvements, conduct bicycle and pedestrian planning; and integrate nonmotorized modes into multimodal models and analyses.[10] Some of the reasons cited for not collecting nonmotorized data included limited budget, staff and resources; an institutional culture that does not consider bicyclists and pedestrians as part of traffic; and the low usage of pedestrian and bicycle facilities.[11]

Count Duration and Timing

Continuous counts capture temporal variation in pedestrian activity, whereas short-duration counts do not. However, since continuous counts require more resources, agencies often use short-duration counts to capture spatial variation. Both types of counts are needed to understand pedestrian travel. While continuous counts are preferred, they are not feasible at all locations because of the higher cost associated with counter procurement and maintenance. Therefore, agencies can institute continuous counts, short-duration counts or a mixture of both. Using factors derived from continuous count stations, short-duration counts are adjusted to derive performance metrics such as annual average daily bicyclists.

A 2003 TRB report by Cottrell et al. provided a pedestrian data framework that could be used to establish a pedestrian data counting program.[12] Chapter 4 of the 2013 TMG built upon reports such as these to outline the steps needed to establish both continuous as well as short-duration data programs. For continuous counts, the steps are as follows:

- Review the existing continuous count program
- Develop an inventory of available continuous count locations and equipment
- Determine the traffic patterns to be monitored
- Establish pattern/factor groups
- Determine the appropriate number of continuous counting locations

- Select specific count locations; and
- Compute monthly, day-of-week (DOW), and hour-of-day (if applicable) factors to use in annualizing short-duration counts. [13]

Elements of short-duration data program are as follows:

- Select count locations
- Choose whether to conduct segment counts (counts taken at a mid-segment location along a nonmotorized facility) or intersection counts
- Select the duration of counts and the type of equipment
- Select the time of year for data collection
- Factor short-duration counts to get an annualized estimate

Count Duration and Timing – Findings

There is research on the optimal length of short-duration bicycle counts, but the project team is not aware of any studies on the length of pedestrian counts. According to the literature on bicycle counting, purpose and available resources often dictate the length of short-duration counts, which are often collected manually.[14] Many agencies conduct two-hour counts, however that is changing based on recent findings. The NBPDP suggests taking a series of two-hour counts over up to three consecutive days or weeks at locations with higher activity levels, and over up to two consecutive days or weeks at locations with lower activity levels[15]. The TMG states that while two-hour data is better than no data, the error rates obtained when factoring two-hour counts may be high, and recommends using 12-hour counts to create a time of day profile.[16] Nordback et al. showed that counting for one full week would minimize error for AADB estimation, and Hankey et al. also recommended week-long counts.[17,18] El Elsawey found that counting for one month significantly improved estimation activity.[19]

Deciding when to conduct counts is another important element in the process of designing a nonmotorized travel counting program. Short-duration counts are typically performed during months that represent average use, which can be identified by studying continuous count data.[20] NBPDP recommends taking counts in mid-May and mid-September. Nordback et al. recommend counting in May-October in climates with winter weather to minimize the effects of seasonal variability,[21] and Hankey et al. recommend counting during April-October for the same reason.[22] El Elsawey found that counting during the summer months produced the lowest estimation error.[23] Pertinent research on the length of counting is presented in the table in the Appendix.

Count Site Selection

Choice of count site locations for continuous and short-duration counts is an important element of the counting program. Site selection criteria often dictate where counts should be collected but they are often not concrete. The TMG provides guidance on continuous site selection.

Count Site Selection – Findings

Continuous Count Site Selection

According to the TMG, site selection for continuous counts is often dictated by criteria such as the degree to which locations are important to system users, and the need to differentiate bicyclists from pedestrians.[24] Jackson et al. provide the following objectives for continuous counter site selection based on research conducted for North Carolina DOT:

- Develop a standardized site selection method that complies with nationally accepted methods for estimating statistics
- Provide standardized site selection methods
- Develop regional site selection method document
- Include multiple stakeholders in the development of regional site selection process
- Develop a site selection method that is most beneficial and efficient in terms of cost, data usage, and technologies[25]

They also provide a list of site selection steps based on the objectives above.

- Gather potential locations – Contact various agencies to get a list of potential sites based on locations where counts have been conducted in the past, and within geographic areas of interest.
- Conduct a site visit – Site visits help refine and prioritize recommended sites. Additional sites may be added based on local knowledge during the site visit.
- Determine recommended continuous count location sites – Sites can be classified as being appropriate for continuous count locations based on observed activity levels, discussions with local contacts and information about origins and destinations.
- Reprioritize site selection recommendation rankings – Based on discussions with local staff, and additional information on factor groups, site selection recommendation rankings developed previously may be revised.
- Gather additional data and select continuous count station sites – Continuous count sites are typically high volume locations that are selected on the basis of their inclusion in a certain factor group.
- Select short-duration sites – Short-duration sites are typically geographically dispersed and provide the necessary spatial spread for a counting program.[26]

Short-duration Site Selection

Research and guidance suggests that transportation agencies are less systemic about selecting sites for short-duration counts than for continuous ones. According to the TMG, the current practice for site selection of short-duration counts is based on practitioner interest and locations with high activity levels.[27] Jackson et al. suggest that short-duration count site selection is a byproduct of the continuous site selection process, as sites that are deemed not suitable for continuous counter placement can be used for short-duration counts.[28] However, locations chosen in such a manner may be biased and not statistically representative.

According to NBPDP, locations for short-duration counts should be selected with the following criteria in mind.[29]

- Locations where historical count data has been collected
- Locations with high collision rates

- Locations with mixed land uses
- Locations close to transit
- Locations based on stakeholder recommendations
- Pinch points in the network
- Representative locations in urban, suburban and rural areas

NCHRP 797 outlines four approaches for selecting count locations: random, representative, targeted and control.[30] In random sampling, sites are chosen randomly, with no consideration of appropriateness of the location for technologies. The risk with simple random sampling is that it may result in sites with high variability, which could lead to high margins of error when estimating volumes. Representative locations are chosen based on available resources as well as spatial coverage. NCHRP 797 suggests the following criteria for representative locations:

- Located in different geographic parts of the community
- Surrounded by different types of land use
- Found on different types of facilities
- Reflective of the range of socioeconomic characteristics of the community[31]

Targeted locations are chosen based on association with a particular project, facility type or other specific characteristics. Examples of such locations are sites with high number of crashes, locations where certain projects have been implemented, and pinch points. Control locations are those that have been unaltered and are typically chosen for comparison with targeted locations.

Technologies

While there are a number of established technologies to count motor vehicles, technologies to count nonmotorized travel are continuously evolving. Many of these technologies have been previously used to count motor vehicles and are being adapted to count bicyclists and pedestrians. Nonmotorized counts, especially counts of pedestrians, are often challenging to conduct because pedestrians are not confined to a particular path or direction and often travel in groups, which makes it hard for a device to distinguish the actual number of travelers. Occlusion, which occurs when two or more people cross the path of the counter simultaneously and the counter only records the person closest to the sensor,[32] is a common risk for pedestrian counting technologies.

A limited number of technologies are available for counting pedestrians, including the following:

- Manual counts in the field
- Manual counts from video
- Automated video counts
- Passive infrared (used in combination with a bicycle specific counting technology)
- Active infrared (used in combination with a bicycle specific counting technology)
- Pressure sensors or mats
- Radio beam

The choice of technology for counting pedestrians often depends on the purpose, duration of counting (short term vs. continuous), location (sidewalk, path, crosswalk etc.) and available resources (cost, personnel etc.). TMG states that the choice of the equipment often rests on two questions: What is being counted and for how long?

Technologies – Findings

The most commonly used technologies are manual counts in-field, manual counts via video or passive and active infrared sensors in combination with other equipment. A table containing pertinent references along with key takeaways for each of the available technologies for counting pedestrians is presented in the Appendix, and more information on technologies for counting pedestrians can be found in NCHRP 797[33]. Below we summarize the key advantages and disadvantages of each counting technology:

- **Manual in-field counts** require more effort than other technologies, but allow for the collection of additional information such as gender and compliance behavior. However, observer inattention and fatigue can diminish the accuracy of manual in-field counts.[34,35,36]
- **Manual counts from video** allow the same advantages as in-field counts and typically produce more accurate results using fewer personnel.[37,38,39]
- **Automated video** is an emerging technology to gather pedestrian counts by tracking pedestrian trajectories. Although it is now commercially available through multiple vendors, its accuracy has not been independently verified[40,41,42,43,44,45]
- **Pressure pads** and **laser scanners** are also capable of counting pedestrians, however their accuracy has not been rigorously tested yet[46,47,48,49]
- **Passive and active infrared devices** are often used to count pedestrians. Since they cannot distinguish between bicyclists and pedestrians, they are often used in conjunction with other bicycle counting technologies. Bicycle counts can then be subtracted from the total count from the infrared device in order to create pedestrian counts. Infrared devices typically tend to undercount and are subject to errors due to occlusion when groups of bicyclists and pedestrians pass by these devices, as well as due to high or low temperatures[50,51,52,53,54,55,56,57]

Count Data Management

Data must be managed so that it can be analyzed and shared. Managing count data requires a repository to store the data and quality checks on the data to ensure validity. Various options are available to manage count data, including spreadsheets, databases, general data management software, vendor supplied software, and cloud-based systems. Many agencies already use databases to manage their motorized counts. Integrating nonmotorized counts into a motorized database can enable agencies to make use of an existing framework and to consolidate all counts into a single database. The 2013 TMG defines a standard data format, which includes critical and optional fields for nonmotorized data, with the intent that data collected in this format could be compared and contrasted with others and submitted to the FHWA Travel Monitoring Analysis System and National Travel Database.

Count Data Management – Findings

QA/QC procedures on nonmotorized data are still evolving and have not been standardized yet. The TMG provides an overview of the quality control checks that are used on motorized data in FHWA's Travel Monitoring Analysis System (TMAS) and outlines four types of possible errors: Fatal, Critical, Caution and Warning[58]. Fatal errors occur when the data is in the wrong format, Critical errors occur when critical columns are missing data, Caution flags are used when records are missing optional data or unexpected data are encountered, and Warning flags are used when duplicate records are submitted.

Tuner and Lasley define three types of error checks: Quality Control Checks, Validity Checks, and Business Rules[59]. NCHRP 797 lists several possible error sources with automated technology and recommends proper validation of the data from the counters and calibration of the counters themselves to reduce erroneous data. NCHRP 797 recommends both cleaning as well as correcting count data before it is used. Cleaning refers to the clearing the database of unusual or incorrect data, whereas correcting count data refers to the development of factors to account for systematic undercounting or overcounting based on the technology and site characteristics.[60]

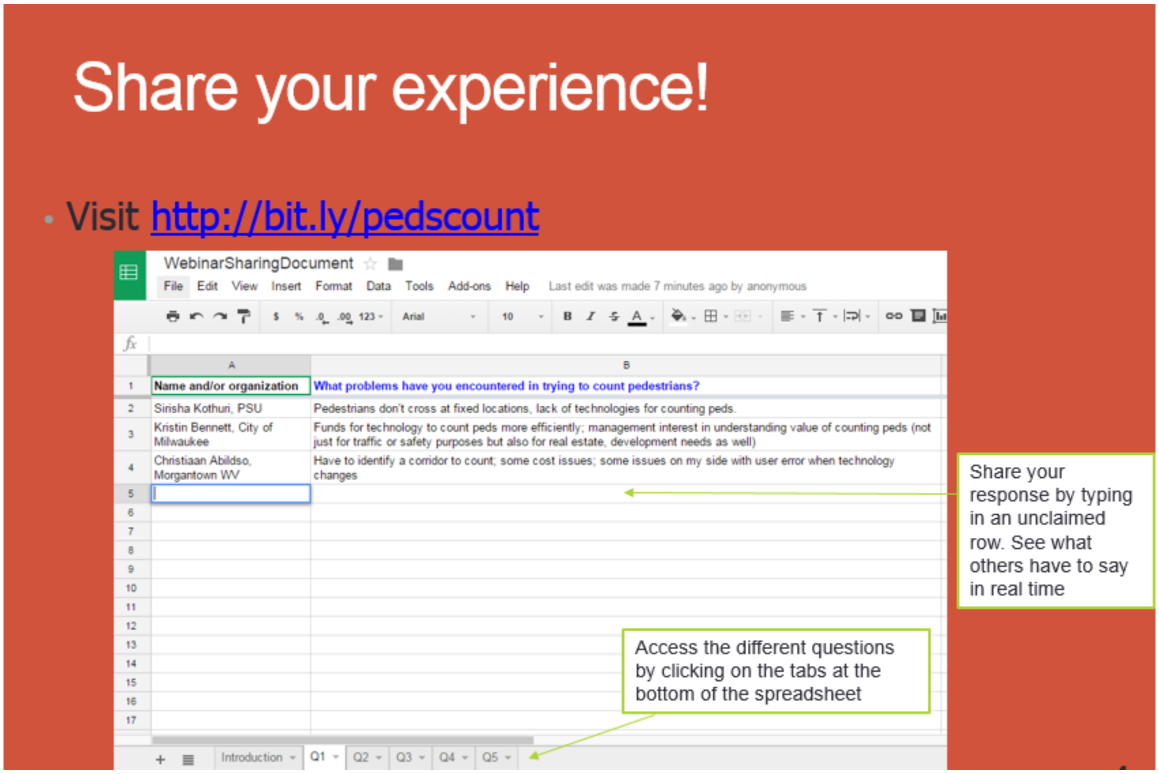
The NBPDP was the first effort to create a national repository for nonmotorized data. Since its inception in 2005, the NBPDP has provided guidance on how to conduct manual short-duration counts, and has accepted and stored nonmotorized data submitted via email. The biggest drawbacks of the NBPDP are that there is no standardized process for storing and archiving data, quality checks are not performed on the accepted data, and the system does not allow electronic access to the data. This means that NBPDP data are not very useful to researchers and other potential users. The TMG formats and associated methods to quality control and store the data through TMAS will provide standardized processes and better data availability.

Los Angeles County created its own online clearinghouse for bicycle count data, but this database does not include pedestrian data, nor can it accommodate continuous counts.[61] Other transportation agencies, including the Delaware Valley Regional Planning Commission[62] and Arlington County, Virginia,[63] also make their data available online. Portland State University's Bike-Ped Portal is the first national effort to create an online archive that is capable of accepting and storing nonmotorized data from a variety of sources while providing easy electronic access to the data and the ability to export the data in different format.[64] This archive is currently in development and is expected to be online in 2016.

WEBINAR WITH PRACTITIONERS

A nationally advertised webinar titled "Pedestrians Count! How to Measure Foot Traffic" was conducted by the Institute for Bicycle and Pedestrian Innovation (IBPI) housed at Portland State University (PSU) to support the development of this report by eliciting voluntarily contributed insights on pedestrian travel counting practices from practitioners across the country. The 90-minute webinar was conducted on August 27th, 2015 In addition to the moderator, a panel of five speakers presented material on pedestrian travel counting techniques. Topics included pedestrian count counting, technologies and sites, count duration and factoring, data management, and counting programs. A portal to gather voluntary feedback from participants was set up in Google Sheets, an online collaborative spreadsheet platform. The link to the Google Sheet was emailed to the registrants prior to the webinar and was also shared often throughout the webinar. Figure 2-1 shows a screenshot of the sharing document.

Figure 2-1. Webinar Sharing Document



Over 300 people attended, with 25 percent reporting that they had multiple people viewing the webinar at their site. Participants represented a broad cross-section of practitioners, from planners and engineers to researchers and citizen advocates. 67% of attendees indicated that they were unfamiliar with the TMG.

Throughout the webinar, we posed five questions to the participants and received a total of 76 responses across all five questions. We summarized responses to each of questions below.

Challenges with Pedestrian Counts

We asked the attendees, “What problems have you encountered in trying to count pedestrians?” Attendees’ responses are summarized below. A total of 14 responses were received for this question.

- Lack of funds for technologies to count more pedestrians more efficiently
- Management interest in understanding the value of counting pedestrians
- Identifying a corridor to count
- Size of the urban area
- Pedestrians do not always follow prescribed routes
- Duration of the counts
- Difficulty counting in high volume locations with manual methods

- Technology limitations
- Identifying reliable long term methods to count
- Resources specifically staff time
- Differentiating between pedestrians and cyclists on shared use facilities
- Vandalism
- Counting latent demand

Cost was identified as a common and significant barrier to counting by participants. Other challenges that were identified by the webinar participants include technology limitations and identifying a reliable technology to perform continuous counts. Another well-known challenge identified by the webinar participants is that pedestrians do not follow well defined routes, thus making it very hard to count them accurately.

Pedestrian Counting Practices Including Technologies and Locations

The second question we posed to the attendees was, “Tell us about your pedestrian counting practices, including technologies and locations.” A total of 31 responses were received and are summarized below.

- Technologies
  - Manual counts
  - Passive infrared sensors (may be combined with pneumatic tube counters to differentiate pedestrians and cyclists)
  - Stereo camera and laser scanner combination
  - Automated video data collection
- Locations
  - Sidewalks
  - Shared use paths
  - Intersection turning movements
  - Trails
  - Crosswalks
  - Corners
  - Greenways
  - Downtown locations
  - Screenline (segment)

Many respondents reported using infrared sensors to count pedestrians at sidewalks and along paths, and automated video and manual counts were also popular. With respect to locations, webinar attendees reported counting along sidewalks, crosswalks, shared use paths and greenways. Some respondents also reported on the types of counts conducted, for example segment versus intersection turning movement counts.

Count Duration and Factoring

Next, we asked attendees to "Describe your short-duration and continuous pedestrian count programs." 12 responses were received for this question. The responses are summarized below.

- Short-duration
  - Peak periods
  - 12-hour counts
  - Three days
  - Seven days

For the short-duration counts, the responses ranged from not having a defined pedestrian counting strategy to counting for one week. Some jurisdictions reported having continuous counts. Some jurisdictions also reported counting pedestrians only during intersection turning movement counts.

Count Data Management

We asked participants to "Tell us about your pedestrian count data management. How do you manage and share your data?" The 12 responses received from the attendees are summarized below.

- Data Storage
  - Access database
  - Project files
  - Website
  - Central traffic management system
  - Custom software
  - National archive
- Data Sharing
  - Local partners
  - By request
  - MPOs
  - Regional partners

The webinar attendees reported using a variety of methods for storing count data, including a national archive, central traffic management system, custom software, access database and individual project files. Data sharing was also prevalent among the attendees, who reported sharing data with local and regional partners.

Counting Programs

Finally, we asked attendees, "What recommendations would you provide give others that are just starting a pedestrian counting traffic program?" The 8 responses received are summarized below.

- Tie it back to performance measures

- Quantify health and economic impact of trails
- Communicate with stakeholders
- Document the process
- Research available technology
- Be flexible
- Connect purpose of the project with the right data collection method
- Research locations
- Develop a strategic plan
- Develop QA/QC method
- Be patient

Some attendees recommended justifying the purpose of the data collection by linking it to performance measures. Other recommendations include researching available technologies and locations, developing a strategic plan for data collection, documenting the process and communicating with stakeholders.

Summary of Webinar Input

The webinar responses provided useful insights into the range of pedestrian counting techniques deployed by various agencies around the country. Many agencies reported significant challenges with counting pedestrians including cost, equipment, resources and lack of defined paths on which to count. In spite of these challenges, many agencies were still conducting counts. Commonly-used technologies included manual methods, infrared devices, and automated video processing technology, and attendees reported conducting counts along sidewalks, paths, crosswalks, trails, corners and neighborhood greenways. Agencies also reported performing both short-duration and continuous counts, with the short-duration counts ranging anywhere from peak periods to one week. There did not appear to be a standard approach to data storage, with agencies storing data either locally or using a data archive. They also reported sharing data with local and regional partners. Attendees had a number of recommendations for others who were just starting a pedestrian counting program. The recommendations included researching available technologies, methods and locations, developing a strategic plan, tying it back to performance measures, and communicating with stakeholders.

Interviews With Practitioners

In addition to holding a webinar the webinar, the research team also conducted telephone interviews to elicit best practice information from a small group of experts across the country. The research team drew the interviewees from various groups likely to be involved and knowledgeable with pedestrian travel counting practices, including academics, vendors, bicycle and pedestrian coordinators, and travel monitoring staff. Figure 2-1 shows the interviewee list.

Table 2-1. Interviewee List

Category	Respondent	Organization
Academics	Dr. Robert Schneider	University of Wisconsin, Milwaukee
	Dr. Greg Lindsey	University of Minnesota
	Dr. Luis Miranda-Moreno	McGill University
State Traffic Monitoring Staff	Steve Abeyta	Colorado Department of Transportation
State Bike-Ped Coordinator	Kenneth Brubaker	Colorado Department of Transportation
State Bike-Ped Planning	Lisa Austin	Minnesota Department of Transportation
City Bike-Ped Coordinator	David Patton	Arlington County, Virginia
Vendor	Jean-Francois Rheault	Eco-Counter
	Stanislav Parfenov	Placemeter
Practitioner	Michael Jones	Alta Planning and Design
Practitioner	Michael Jones	Alta Planning and Design
Business Alliance	Aylene McCallum	Downtown Denver Partnership
Non-Profit	Dr. Tracy Hadden Loh	Rails-to-Trails Conservancy

We conducted interviews between August and October of 2015 via telephone. We asked each interviewee various questions pertaining to their experience with pedestrian counting programs, technologies, site selection, count data management and specific recommendations for the TMG. To comply with Office of Management and Budget (OMB) regulations, each question was asked of no more than 9 interviewees. Below we summarize interviewees' responses by category. Complete notes from each interview are in the Appendix.

Establishing Pedestrian Counting Programs

According to respondents, most agencies that establish nonmotorized traffic counting programs are primarily focused on counting bicycles, not pedestrians. Though pedestrians account for a larger portion of travelers than cyclists, establishing an effective pedestrian count program is a complex task, and there is less supporting research and guidance available. Many respondents stated that their pedestrian counting programs were in the nascent stage.

Minnesota Department of Transportation (MnDOT) started its program in 2010-2011 in collaboration with the University of Minnesota. Initially, MnDOT collected short-duration manual counts, but it is working to accommodate continuous counts. Colorado Department of Transportation (CDOT) has been deploying counters that collect both pedestrian and bicycle counts, mostly along trails, since 2010. Arlington County, Virginia collects uses collects data from both manual counts conducted by volunteers and automated counters.

Challenges with Counting Pedestrians

Respondents described a number of challenges in counting pedestrians. Many reported errors due to occlusion, especially when counting at high volume locations. Interviewees also mentioned difficulty in identifying sites and technologies since pedestrians also do not follow a definite path or route and exhibit more free range of movement than cyclists. Though manual counts are commonly used, interviewees said that they are expensive and are not feasible at every location. At the same time, interviewees reported that existing technologies typically have high error rates. There is also lack of understanding on pedestrian travel patterns.

Technologies

Though many interviewees reported conducting manual counts, several reported using emerging automated count technologies, either to collect continuous counts or conduct short-duration counts over a longer time period. Most respondents reported using infrared counters to count bicycles and pedestrians together, or deploying infrared counters in conjunction with bicycle-specific counters such as pneumatic tubes or loops to differentiate cyclists from pedestrians. Interviewees reported more limited use of automated video processing, and mentioned several emerging technologies with potential for more widespread deployment, such as thermal cameras, portable mats, ultrasonic devices, LIDAR, and using wireless detection to assess travel patterns, speeds and origin-destination information for pedestrians. One respondent stated that no single technology would be able to tell the entire story, so it is necessary to combine data from different sources to understand pedestrian travel.

Site Selection

Most respondents stated that site selection often depends on the purpose of the data collection. According to one interviewee, if an agency is installing counters for the first time, it is more beneficial to install the first counters at locations with high activity levels to build political support for the counting program. Once the support has been established, the agency can add low volume locations also to get network coverage. Stakeholder recommendation was also deemed an important factor in site selection. Other considerations for site selection mentioned by interviewees include cost and power for the equipment. Respondents also stated that it was difficult to justify picking sites randomly given these other considerations.

We also asked respondents if they counted at non-traditional locations such as overpasses and underpasses, elevators, escalators and stairways. Some respondents stated that they did count at these locations, but typically they were project-specific temporary counts to demonstrate facility usage, justify the need for improvements, or assess disabled access. One interviewee reported encountering vandalism of an automated counter used for a short-duration count in a stairway. Counting at these non-traditional locations is important, otherwise it would be impossible to know how many people are using these facilities. In France, counts on elevators, escalators and stairways were undertaken by French railway as part of a large project. One interviewee also noted the need to count pedestrians on shoulders of rural roads.

Count Data Management

While motorized counting programs are well established, nonmotorized programs are still evolving, and agencies are still trying to determine how best to manage their count data. Many interviewees reported using vendor-developed cloud-based software to manage their count data. CDOT has adopted new travel monitoring software that is capable of storing nonmotorized data as well. A few respondents stated that their choice of a particular technology for counting was based on the availability of an integrated data management system by the equipment vendor. Many respondents stressed that it was important to archive the raw data as well. For devices that do not have vendor supported software, respondents reported creating their own scripts to format data.

Quality Checks

Many respondents unequivocally stressed the need for quality checks in order to ensure good quality data. The respondents also stated the importance of calibrating the equipment and validating the data. One respondent reported using four-hour manual counts to check each automated counter. Respondents reported performing quality checks on count data either manually or via software. Typical quality checks included visual inspection of the data to identify equipment malfunction, identifying large periods with zero counts, large data gaps, checking count values against historical averages to identify outliers and verifying directional split (if counting both directions). Respondents reported the need for setting different tolerances based on volumes at the site. Volume is an important consideration because below a certain threshold, quality checks may become irrelevant. Therefore, lower tolerances are needed at higher volume locations.

Data Sharing

Data sharing practices differed based on agency. While some interviewees reported sharing data with local partners or made data publicly available through a website, other interviewees said that their agencies lacked the data to share resources. However, most respondents agreed on the need to share data.

Equipment Procurement

Some respondents reported challenges in procuring equipment due to agency regulations requiring bids from multiple vendors, which were not always available because of the limited number of technologies available. These interviewees worked with their agency's procurement office to list a preferred vendor as a sole source provider of the equipment, which allowed partner agencies to purchase additional equipment easily without going through the bidding process. Respondents recommended involving having personnel who understand counting equipment involved in the procurement process, and emphasized the need to test the equipment prior to procurement to understand its accuracy and determine if it meets data collection needs.

Recommendations for the TMG

Some interviewees recommended specific improvements to the TMG. One respondent suggested that the TMG should include several different pathways for communities to count pedestrians; for example recommending one set of counts to determine overall walking rates and another to determine exposure to collisions. Another interviewee recommended providing national factors for estimating total volumes based on short-duration counts. Other recommendations included adding procedures to count pedestrians on rural shoulders, developing additional guidance on adjustment factors for short-duration counts, site selection criteria for continuous counters, including more case studies on how pedestrian data is being used, and adding guidance on collecting survey data in the TMG.

One respondent reported difficulties with presenting data in the format recommended in the TMG. Another raised a broader question about whether the general approach to nonmotorized count programs outlined in the TMG, which mirrors approach for motorized count programs, is appropriate for pedestrian data. This interviewee suggested that given the scant resources available to conduct pedestrian counts and the inherent variability of pedestrian data, agencies should consider focusing on project level counts as opposed to counting everywhere.

CURRENT PRACTICE – SUMMARY OF FINDINGS

Counting pedestrians is an important but challenging task. Pedestrian activity is localized and heavily influenced by land use, pedestrian movements are not constrained to a given path, there are few automated technologies that capture pedestrians well, and some of the emerging technologies have not been widely tested. Our review of the academic literature, coupled with feedback received during the webinar and interviews with experts, reveals that most agencies that collect nonmotorized count data are further along with bicycle data collection and counting than pedestrian data collection.

Table 2-2 shows an overview of pedestrian counting programs, which was compiled using the webinar and interview responses.

Of the 17 agencies with pedestrian count programs that we identified through our interviews and webinar, most (70 percent) indicated that infrared equipment is used for counting pedestrians. All but two agencies reported collecting short-duration counts, most of which (60 percent) were collected manually. A minority of responding agencies (35 percent) reported collecting continuous pedestrian counts. Only 30 percent of the respondents mentioned counting at intersections, while a majority (60 percent) indicated that they count on trails and paths. Sidewalks and mid-block crossings were also mentioned as count locations by multiple agencies. Only a third of respondents mentioned having both short-duration and continuous pedestrian count programs.

Following is a list of recommended current practices that emerged from the research described in this section.

- Develop a strategic plan for counting pedestrians that includes both continuous counts and short-duration counts
- Develop site selection criteria
- Count at high volume and low volume locations
- Count at pedestrian facilities other than sidewalks and intersections (e.g., overpasses, underpasses, stairs, elevators, and escalators)
- Choose equipment based on purpose, location, duration of counting and available resources
- Calibrate equipment and validate data during installation and regularly thereafter to ensure robust and reliable data
- Perform QA/QC checks on the data before it is used
- Use a web or cloud for storage
- Keep both raw and adjusted (cleaned) data
- Share data
- Develop visualizations and performance metrics based on data

Our research also revealed a number of potential topics for further research:

- Understand and study pedestrian travel patterns
- Develop adjustment factors and create factor groups for pedestrian travel
- Continue to test and evaluate new pedestrian counting technologies
- Establish QA/QC standards for pedestrian count data
- Develop site selection criteria for continuous and short-duration count locations

Table 2-2. Overview of Pedestrian Counting Programs

Count Programs	Types of Counts	Duration	Automated Technologies	Locations
Minnesota DOT	■ Manual ■ Automated	■ Short-duration ■ Continuous	■ Infrared ■ Radiobeam ■ Microwave	■ Trails ■ Sidewalks ■ Mid-block crossings ■ Rural shoulders ■ Overpasses
Colorado DOT	■ Manual ■ Automated	■ Short-duration ■ Continuous	■ Infrared	■ Trails ■ Sidewalks
Georgia DOT	■ Manual	■ Short-duration	■ Cameras	■ Mid-block crossings
Illinois DOT	■ Manual ■ Automated	■ Short-duration	■ Automated video	■ Not indicated
North Carolina DOT	■ Automated	■ Short-duration ■ Continuous	■ Infrared	■ Segment (Screenline) ■ Sidewalk ■ Shared use paths
Virginia DOT	■ Manual ■ Automated	■ Short-duration	■ Automated video	■ Intersection ■ Segment (Screenline)
Michigan DOT	■ Automated	■ Short-duration	■ Automated video	■ Intersection turning movement
City of Milwaukee, WI	■ Manual ■ Automated	■ Short-duration	■ Infrared	■ Trails ■ Intersection turning movement
New York City DOT	■ Manual ■ Automated	■ Short-duration	■ Automated video	■ Crosswalks ■ Corners ■ Sidewalks
Greensboro, NC	■ Automated	■ Short-duration	■ Infrared ■ Automated video	■ Sidewalks ■ Greenways
City of Bettendorf, IA	■ Automated	■ Not indicated	■ Infrared	■ Trails
Columbus, OH	■ Automated	■ Short-duration	■ Infrared	■ Downtown locations ■ Shared use paths
Menasha, WI	■ Manual ■ Automated	■ Short-duration	■ Infrared ■ Automated video	■ Not indicated
Morgantown, WV	■ Automated	■ Continuous	■ Infrared	■ Trails
Region of Waterloo, Canada	■ Automated	■ Short-duration	■ Infrared	■ Turning movement
Philadelphia, PA	■ Manual ■ Automated	■ Short-duration ■ Continuous	■ Infrared	■ Trails
Arlington County, VA	■ Manual ■ Automated	■ Short-duration ■ Continuous	■ Infrared	■ Trails

3. PEDESTRIAN COUNT DATA COLLECTION EQUIPMENT

Counting pedestrians is a critical but challenging task. Pedestrian counts can be used to analyze safety, assess economic impacts, and monitor trends to justify the need for new facilities. There are several challenges associated with counting pedestrians. Pedestrians do not travel along defined paths, which complicates the process of deciding where and how to place counters. Pedestrians often travel in groups, which also leads to the issue of occlusion, when automated counters capture only one pedestrian among several. The limited array of available technology for counting pedestrians exclusively also adds to the challenge. Nevertheless, many agencies are investing in both short-duration and continuous pedestrian counting programs.

An important consideration in these programs is determining the appropriate technology that can be used for counting pedestrians at a variety of locations such as sidewalks, crosswalks, multi-use paths, overpasses, underpasses, and vertical transportation (elevators, escalators and ramps). Understanding how the data will be used is important when developing the counting approach. Other important factors that also need to be considered include installation and procurement of the equipment and resource allocation strategies. Calibration frequency and assessing accuracy of counting equipment are also critical. The following subsections describe and summarize findings from the team's research on available technologies and strategies for installation, procurement and resource allocation, calibration and validation.

TECHNOLOGIES

Technologies for counting pedestrians are continuously evolving, but in general there are fewer technologies available to count pedestrians than there are for counting bicyclists. Prominent pedestrian counting technologies include manual counts (both in-field and from video), automated video counts, passive and active infrared devices, and radio beams. Thermal cameras, laser scanners, and pressure or acoustic pads are also capable of counting pedestrians, but are used less frequently. Other technologies can capture surrogate measures of pedestrian traffic volumes measure pedestrian activity via Bluetooth[65] or Wi-Fi technology,[66] or traffic signals that record pedestrian pushbutton actuations.[67] Both the TMG and NCHRP 797 provides an extensive review of counting technologies.[68, 69] The available technologies along with their strengths and weaknesses are summarized below in Table 3-1. More details on each technology is provided in Appendix B.

Table 3-1 Pedestrian Counting Technologies

Technology	Typical Applications	Strengths	Weaknesses
Manual Counts In-Field[70,71]	Short-duration counts	▪ Can gather gender and behavioral information ▪ Portable ▪ No installation costs	▪ Limited to short-duration counts only ▪ Accuracy may depend on data collector ▪ At high-volume locations, additional personnel are needed, which can result in higher costs
Manual Counts from Video[72,73]	Short-duration counts	▪ Can gather gender and behavioral information ▪ Video can be reviewed in the office, data collector can view the video at fast and/or slow speeds to extract counts ▪ If existing cameras are available, costs can be low	▪ Limited to short-duration counts only ▪ Frequent visits may be required to download data, replace batteries ▪ Data reduction is labor intensive ▪ Equipment may be susceptible to theft or damage
Automated Counts from Video[74,75]	Short-duration or continuous counts	▪ Portable ▪ Time effort is low ▪ Video can be used for additional purposes	▪ May be expensive to collect data at several locations
Passive Infrared[76,77]	Short-duration or continuous counts	▪ Portable, easy to install ▪ External power source not required	▪ Cannot distinguish between bicyclists and pedestrians, unless combined with bicycle specific counting equipment ▪ Cannot be used for crosswalks ▪ Occlusion errors may result if large groups of pedestrians are crossing simultaneously ▪ Extreme ambient temperatures may affect accuracy

Technology	Typical Applications	Strengths	Weaknesses
Active Infrared[78,79]	Short-duration or continuous counts	▪ Portable, easy to install ▪ Error is linear, a factor can be used to provide accurate counts	▪ Cannot distinguish between bicyclists and pedestrians, unless combined with bicycle specific counting equipment ▪ Not suitable for on-street monitoring ▪ Occlusion errors may result if large groups of pedestrians are crossing simultaneously ▪ Requires fixed objects or poles on either side of path or trail
Radio Beam[80]	Short-duration or continuous counts	▪ Portable, easy to install ▪ Does not need external power source	▪ Occlusion errors with large groups of pedestrians ▪ Requires fixed objects on either side of trail or path to mount transmitter and receiver
Pressure and Acoustic Pads[81,82]	Continuous counts	▪ Less prone to vandalism due to in-ground installation	▪ Mostly used on unpaved trails ▪ Requires users to pass directly over the sensor
Thermal Cameras[83]	Continuous counts	▪ Not available	▪ Not available
Laser Scanners	Short-duration or continuous counts	▪ Not available	▪ Not available

PURCHASING STRATEGIES

Purchasing and procuring equipment is a critical step in establishing counting programs. Once an agency has identified the appropriate automated equipment for its counting program, it is important to choose the right vendor. NCHRP 797 lists a number of issues that an agency must consider during the procurement process:[84]

- Will the equipment arrive ready to be installed in the field right out of the box, or will it need to be assembled?
- Does the equipment require other products and services to function?
- What is the warranty and expected life of the equipment?
- What are the specifications of the site that are required for the equipment to function correctly?
- What site characteristics must be avoided for proper functioning?
- How long does it take to install and calibrate the equipment? What kind of installation support will be provided by the vendor? How often should it be verified or calibrated (frequency of calibration)?
- Does the equipment installation require contractor services?
- What are the specific security features on the equipment?
- What are the options regarding purchasing or leasing the equipment?
- What are the options for downloading the data? How is the data formatted? Are the TMG formats available?
- How have others used this equipment?
- What type of customer service will be provided with the equipment purchase?

Information about procurement strategies was also provided by some interviewees during the interview process, as described in Chapter 2. Some respondents reported difficulties early in the procurement process due to agency rules and regulations requiring bids from multiple vendors, which were not always available for emerging technologies. These interviewees reported working closely with the procurement office to list a preferred vendor as a sole-source provider of the equipment and include them in in the vendor-approved list. That designation allowed other agencies in the region/state to purchase additional equipment easily without going through the bidding process. Respondents recommended involving personnel in the procurement process who understood the equipment and the process of counting pedestrians, as well as testing the equipment prior to procurement to understand its accuracy and determine if the equipment meets an agency's data collection needs and purpose.

INSTALLATION STRATEGIES

Installation of the equipment is an important but challenging part of the data collection process. NCHRP 797 provides a checklist that can be followed by agencies before, during and after the installation process.[85]

Before Installation:

- Conduct a site visit to identify specific location

- Obtain necessary permits and permissions required for the installation
- Create a site plan, that shows details of the installation location
- Hire a contractor if necessary for installation
- Arrange an on-site coordination meeting with the relevant personnel
- Check for any potential problems
- Is having power or communications to the location necessary and if so is it available?
- Document the before installation decisions and why certain decisions were made

During Installation:

- Review the site with vendor and other personnel
- Prepare the site for installation
- Take detailed notes and pictures to document the site before and during installation
- Maintain a safe work zone during the installation process
- Install the counter according to vendor specifications
- Take detailed notes and pictures during the installation to document the process
- Sync the clock on the equipment with the correct time
- Verify that the device is working correctly by conducting manual counts
- If the counts are not accurate, calibrate the device and repeat the validation process by conducting manual counts again
- Verify communication (if needed) is working at the site
- Check the earth ground of any installed equipment and that suitable lightning protection is provided

After Installation:

- Take pictures of the device and vicinity
- Take picture of the detection zone and mark the detection zone
- Place copies of the installation documentation at the site and back in the office for future reference, if possible.
- Create a site description diagram that shows pictures and contains notes about the installation process

Periodically following installation:

- Revisit the site at least every 3 months to ensure that the equipment is working correctly
- Assess the data from the equipment to detect any anomalies

VALIDATION AND CALIBRATION

Once automated counting equipment has been installed, data should be validated by comparison to manual count data (manual count from the video is best). NCHRP 797 recommends two sets of validation, one directly after the equipment has been installed, and the other a few days after installation.[86] Both validation procedures involve comparing the equipment counts to manual counts to detect problems with accuracy and abnormalities in the data. Depending on the outcome of the validation process, the equipment may need to be calibrated, which involves adjusting the parameters on the device so that it can count accurately. NCHRP 797 recommends consulting vendors to enquire about installation and calibration support including providing ongoing calibration support. Counting equipment should be regularly tested to determine if the equipment is producing accurate counts. NCHRP 797 recommends testing for accuracy at least once per year and recalibrating the equipment if the accuracy is not adequate.[87] Validation and calibration should be performed whenever changes in the equipment occur.

RESOURCE STRATEGIES

Establishing a counting program requires a considerable amount of resources. Both the TMG and NCHRP 797 provide extensive information on each particular technology and the resources required to procure, install and maintain the devices. Following is a list of costs that an agency must budget for:[88]

- Equipment cost: This includes the cost of the counters. NCHRP 797 states that using automated counters for short-duration counts costs more than conducting manual counts. Procuring a greater number of counters may lower the cost per counter.
- Preparation cost: This includes the cost of time to identify sites and apply for the necessary permits, as well as the cost of permits, if applicable.
- Installation: This includes the time and materials required for installation of the equipment.
- Hourly cost: For manual counts, hourly labor costs should be taken into account.
- Data collection training: This includes the costs required to train the personnel to retrieve data from a device or conduct manual counts. For manual counts, data collectors need extensive training to gather data accurately.
- Mobility: If the equipment is portable, the cost of moving the equipment to various locations to collect counts should be considered.
- Testing and adjustment: Once the counters have been installed, staff will spend time calibrating and validating the data.
- Expected life: Agencies may also have to budget for maintenance and eventual replacement of counters.
- Battery life: The types and duration of batteries vary between devices and vendors. The duration of battery life has a bearing on maintenance costs. Some devices may directly connect to a power outlet, whereas others may use solar power to charge the battery.
- Data storage capacity and downloading capability: The device's data storage capacity determines how frequently the data will have to be downloaded from the device. Some devices directly upload the data to a central server directly from the field, whereas others may need to

be downloaded manually—more frequently when storage capacity is lower—which will require staff time.

- Database creation: Creating a database to host the count data requires staff time.
- File format: For manual count data and some automated data, it takes staff time to enter the data in a usable format. Using a documented data format long term is most effective. Documented data formats among different local agencies also assists with data portability and knowledge sharing.
- Data cleaning: For the count data to be useful, QA/QC procedures need to be developed and implemented on the data and settable by individual site to best check for local conditions.

PROCEDURES BY FACILITY TYPE

This subsection recommends procedures for pedestrian traffic counting related to the type of facility monitored, including sidewalks and pedestrian-only trails, crosswalks, shared use paths, vertical transportation (stairways, escalators, elevators, etc.), overpasses and underpasses, and plazas. Each facility type poses unique challenges that warrant consideration. We define the six facility types as follows:

- **Sidewalk** is defined in the MUTCD as "that portion of a street between the curb line, or the lateral line of a roadway, and the adjacent property line or on easements of private property that is paved or improved and intended for use by pedestrians."[89] We include another facility type, pedestrian-only trails, in the discussion of sidewalks because they are also pedestrian-dominated spaces. **Pedestrian-only Trails** are facilities with a separate right-of-way from the roadway, intended specifically for pedestrians, common in parks or between buildings on campuses. They can be either paved or unpaved. These are discussed as part of sidewalks.
- **Crosswalk** is defined in the MUTCD as "(a) that part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs or in the absence of curbs, from the edges of the traversable roadway, and in the absence of a sidewalk on one side of the roadway, the part of a roadway included within the extension of the lateral lines of the sidewalk at right angles to the center line; (b) any portion of a roadway at an intersection or elsewhere distinctly indicated as a pedestrian crossing by pavement marking lines on the surface, which might be supplemented by contrasting pavement texture, style, or color."[90] This definition includes two types of crosswalks, marked and unmarked, and crosswalks both at intersections and midblock.
- **Shared Use Path** is defined in the MUTCD as "a bikeway outside the traveled way and physically separated from motorized vehicular traffic by an open space or barrier and either within the highway right-of-way or within an independent alignment. Shared-use paths are also used by pedestrians (including skaters, users of manual and motorized wheelchairs, and joggers) and other authorized motorized and non-motorized users."[91] We discuss two types of shared use paths:
  - A **near-road shared use path** parallels a roadway within its right-of-way, similar to a sidewalk, though usually wider.
  - A **far-from-road shared use path** is either in a right-of-way separate from any road, such as a rail-trail conversion, or parallels a limited-access highway such that at-grade crossings with roadways are infrequent.

- **Vertical Transportation** includes public stairways, ramps, elevators, and escalators and associated landings. This includes "staired streets" defined in WSDOT's Pedestrian Facilities Guidebook as "street rights-of-way on hillsides which have been developed as stairs for pedestrians, not roadways for motor vehicle use."[92]
- **Overpass** refers to "a grade separate facility designed to allow non-motorized traffic to pass over top of a roadway (e.g., a pedestrian bridge)."[93] **Underpass** refers to "a grade separate facility designed to allow non-motorized traffic to cross underneath a roadway (e.g., a pedestrian undercrossing)."[94]
- **Plaza** refers to open pedestrian-only areas. They are often found in city centers, such as city squares and pedestrian malls; on college campuses, such as grassy or paved quadrangles; and even in some business parks.

These facility types are primarily associated with segment or screenline counts, with the exception of pedestrian counts at crosswalks, which are often included in intersection counts, especially turning movement counts. In this document we use the term "segment" as an adjective to describe counts on a road or path segment between intersections instead of the term "screenline" used in TMG Chapter 4. This is to avoid confusion with the alternative definition of "screenline" commonly applied to cordon counts around a city or region.

Below we discuss findings from the (often limited) academic literature, webinars, and interviews related to procedures for counting pedestrians at the facility types listed above.

Sidewalk

Sidewalk counting is challenging because, as noted in the TMG, "Pedestrians take shortcuts off the sidewalk or cross streets at unmarked crossing locations."[95] Another complication noted in the TMG is that even though sidewalks are intended specifically for pedestrian use, bicyclists, skateboarders and others often use sidewalks. Current guidance from the TMG states that "… sidewalks or walkways can be instrumented with a single-purpose infrared counter if bicyclists are not typically present."[96]

Based on interviews and webinar feedback, the study team determined that state DOTs in Minnesota, Colorado, and North Carolina and city DOTs in New York City and Greensboro, NC are counting pedestrians on sidewalks. Agencies indicated that they use manual and automated counting equipment, primarily passive infrared but also radio-beam, on sidewalks. Greensboro, NC mentioned difficulties finding poles from which to mount infrared counting equipment. New York City mentioned difficulties using manual counts on high-volume sidewalks with 6,000 to 7,000 pedestrians per hour, such as those near Times Square.

Pedestrian-only trails, such as those common in parks, are often counted using passive infrared due to relatively low cost and ease of installation. Pressure pads and acoustic mats are also used in some unpaved trails, since they can be buried, preventing vandalism.

Crosswalk

The TMG includes crosswalks as one of the count location types, but provides no specifics on how such counts should be conducted other than a brief mention of pedestrian detection in crosswalks using infrared detection and pressure sensors at curbside pedestrian waiting areas, noting that this is more common in western Europe[97].

Webinar participants talked about counting at crosswalks as part of intersection turning movement counts, which are usually conducted manually in the field or via video. Webinar participants from New York City reported counting pedestrians in crosswalks manually, but staff manual counters had trouble capturing all pedestrians at high-volume crossings with 5,000-plus pedestrians per hour. Georgia DOT mentioned that they were working on a research project to create an "automated mid-block pedestrian counter" to reduce the staff time needed to conduct counts for crossing warrants, but the project would result in only one unit being available for the whole state. Migma Systems reported in the webinar that they have a product capable of counting pedestrians at crosswalks using a combination of stereo camera and scanning laser which can differentiate pedestrians in groups.

Interviewees mentioned that pedestrian research in the San Francisco Bay Area has found that there are some differences in hourly travel patterns between sidewalks and crosswalks even if they are immediately adjacent to one another, so it is best to count on the facility of interest.[98] However, most automated equipment is not applicable at crosswalks. For example, the commonly used passive infrared counters cannot be used at most crosswalks because they also record passing motor vehicles. This makes sidewalk counts a logical surrogate for crosswalk counts.

Video image recognition and manual counts are usually only used for short-duration crosswalk counts because of the high cost per hour. If video is used and either counted manually or by video image processing, it is helpful to mount the camera high enough to be able to look down on pedestrians and avoid occlusion. For example, one video-image-recognition vendor recommends 30 to 90 degree angle from horizontal and minimum height of eight feet.[99]

Kothuri used pedestrian pushbutton data as a surrogate for pedestrian crossings[100]. While this surrogate measure does not capture pedestrian traffic volumes, it does indicate crossings with high and low pedestrian activity.

In summary, crosswalks pose unique challenges to pedestrian traffic counting. Because they cross perpendicular to motor vehicle traffic, detection is more challenging, and pedestrians often do not cross exactly in path of the crosswalk. Currently, manual in-field counts, manual counts from video, and automated video counts are commonly used at crosswalks. Technologies that are available but less common include stereo camera with laser scanner. Follow-up with GDOT on their research project to develop a new technique is warranted.

Shared Use Path

Webinar participants involved in pedestrian counting mentioned using infrared counters to count pedestrians on paths, trails and greenways. Participants reported using passive infrared counters alone to count all warm bodies on a path, which includes bicycles, skateboarders, and others in addition to pedestrians. However, it is important to differentiate pedestrians from other path users since they often have different travel patterns and volumes. Other participants mentioned using passive infrared counters in combination with inductive loops or pneumatic tubes to separate bicyclist counts from pedestrian counts. Where tubes are used, small diameter pneumatic tubes are best to reduce trip hazards and improve count accuracy.[101]

For unpaved shared use paths, such as rural rail-trails, pressure pads can also be used to distinguish pedestrians from bicycles during counts.

Vertical Transportation

Two interviewees described specific cases in which pedestrians were counted on vertical transportation facilities. Rails-to-Trails Conservancy reported collecting short-duration pedestrian counts on a stairway using an automated infrared counter. They mentioned that vandalism was an issue and emphasized the importance of hiding the equipment and checking on it regularly. One of the vendors interviewed described installing pedestrian counting equipment on elevators, escalators and stairways as part of a large project for the French railway system.

Overpasses and Underpasses

MNDOT indicated in an interview that they were counting on overpasses. Dr. Greg Lindsey specifically mentioned that pedestrian counts in downtown pedestrian overpasses, known as "skyways," to demonstrate the use of these facilities to decision-makers.[102] Rails-to-Trails Conservancy also reported experience counting at underpasses and overpasses on far-from-road shared use paths, but did not share any specific concerns about such locations.

Plazas

Plazas are areas where pedestrians may choose to congregate or pass through. Each pedestrian may choose a unique route through the plaza. The TMG describes counts in such environments as "general activity counts." Some manual count methodologies track pedestrian travel through a plaza, while others count pedestrians at points of entrance. Bluetooth and Wi-Fi detection have been used to monitor pedestrian activity on plazas such as the National Mall, but cannot provide total counts since not all people carry Bluetooth or Wi-Fi enabled devices[103].

Other facilities

Interviewees and webinar participants also mentioned conducting counts at other locations not listed above:

- **Road shoulders**: One interviewee mentioned the need to count pedestrians traveling on the shoulder of rural roads. While such volumes are usually low, this information is important to understanding pedestrian safety in rural areas.
- **Unmarked midblock crossings**: Counting unmarked midblock pedestrian road crossings where crosswalks are not present is important for understanding pedestrian safety.[104] Data can be used to assess if a crosswalk is needed or to quantify exposure to collision. However counting pedestrians crossing a roadway where no crosswalk is present is a difficult task, even for a manual counter, because such crossings may be infrequent and could occur anywhere along a road segment. These challenges are similar to those involved in quantifying wildlife crossings on rural roads, where infrared, motion-sensing trail cameras inside metal utility boxes are often used.[105] Sprinkle Consulting uses wildlife cameras to monitor mid-block locations to assess crosswalk needs. The project team is not aware of any cases where video image processing or any other automated techniques have been used to count pedestrians in such situations. For pedestrians, such crossings may be concentrated in areas where there are transit stops, schools or other pedestrian attractors. Focusing observation in the vicinity of such pedestrian attractors may make manual counts feasible.

DATA COLLECTION EQUIPMENT – SUMMARY OF FINDINGS

When counting pedestrians, it is critical to choose the right technology for the count purpose, setting, and duration. Once the appropriate technology has been chosen, proper installation, calibration and validation (for automated equipment) are essential to ensuring good quality counts.

Agencies also need to assess how best to strategically allocate limited resources when managing counting programs. In general, it is best to monitor pedestrian traffic at constrained points in order to reduce error from occlusion (one pedestrian hiding another, for example) and in pedestrian-only environments, to minimize the counting task. Surrogate measures of pedestrian counts such as Bluetooth and Wi-Fi counting and pedestrian push button actuation logs may provide useful supplements to pedestrian count data, to help improve estimates of pedestrian volumes where counts are not collected.

Since technologies are continuously evolving, future innovation and development may bring new or improved technologies to the field of pedestrian counting that my improve data collection and improve pedestrian traffic counting. Continuing to watch and study these developments will be helpful for the future of pedestrian traffic counting.

Specific recommendations for automated counting of the facility types are listed below in Table 3 2. Note that manual counts (both in-field and from video) can be used at all facilities, but we only discuss specifics of manual counting are only included in regard to crosswalks, non-crosswalk road crossings, and shoulder counts.

Table 3-2. Recommendations for Counting Pedestrians by Facility Type

Facility	Intersection / Segment?	Automated Technologies Used	Specific Recommendations
Sidewalks (and pedestrian-only trails)	Segment	Passive infrared, active infrared, automated counts from video	Point infrared emitters toward a wall or another non-reflective, non-moving surface, and do not install infrared receivers in direct sunlight. Video is best collected from above to prevent occlusion.
Crosswalks	Intersection	Automated counts from video, pedestrian push button actuation	Video is best collected from above, if possible, to prevent occlusion.
Shared use paths	Both	Passive or active infrared in combination with inductive loops or pneumatic tubes to distinguish cyclists; pressure pads (if unpaved)	If tubes used, small diameter are best, to reduce trip hazard and increase accuracy.
Vertical transportation	Segment	Passive infrared, active infrared, pressure pads, thermal cameras	Install equipment in a secure location to prevent vandalism.
Overpasses and Underpasses	Segment	Passive or active infrared, alone or in combination with inductive loops or pneumatic tubes to distinguish cyclists	It can be difficult to place equipment on bridge decks; an alternative is to place it at approaches.
Plazas	General activity	Wi-Fi/Bluetooth detectors	Manual counts can be used to track paths through plazas or conducted at points of entrance.
Road shoulder*	Segment	None	Further research is needed
Pedestrians crossing not at crosswalks*	Segment	Infrared motion-activated cameras	Further research is needed.

* Manual counts from video are probably the most viable option for these facilities because the ability to fast forward makes to process of counting infrequent events more efficient. Infrared motion-activated cameras like those used to monitor wildlife crossings can also be used.

4. STRATEGIC CONSIDERATIONS FOR PEDESTRIAN COUNTING PROGRAMS

As described previously in this report, the emphasis on and quantity of pedestrian volume data has increased significantly in recent years. Counting efforts should be part of a broader program to monitor pedestrian traffic. Understanding the ultimate goal of how count data will be used is important when developing the travel monitoring program.

Much as with other elements of pedestrian counting programs, including count technologies and installations, the state of the practice regarding the duration and frequency of counts has been rapidly evolving. This temporal aspect of pedestrian counting has a significant impact on resource allocation and, even more importantly, the quality of the resulting data. This chapter discusses the distinction between continuous and short-duration counts and the concepts of temporal variation and factor pattern groups. The state of the practice is described, including potential topics about which additional research would be beneficial.

BACKGROUND

Continuous and Short-duration Counts

In terms of the temporal period during which they are conducted, pedestrian volume counts have historically been classified as either continuous or short-duration. Continuous counts are conducted via automated devices for a period of 24 hours each day over all days within a reporting year. Short-duration counts are those conducted less than an entire year, frequently for several hours within a day or for multiple days, but also for as long as several weeks. Continuous counts are therefore generally thought of as providing temporal data because they include the full spectrum of potential analysis time periods. Providing such counts across a network of facilities is impractical, however, so short-duration counts provide companion spatial data because they are able to be conducted over a broader area. While many short-duration counts are conducted purely to provide this geographic coverage, others are done for project-specific reasons (e.g., facility sizing needs, before and after studies).

For many reporting and tracking reasons, transportation agencies are often interested in the amount of pedestrian travel that occurs over the period of a year, sometimes referred to as Annual Average Daily Pedestrian (AADP) traffic. By their nature, continuous counts do not have an associated count duration and, aside from any missing data periods due to equipment failure or other unexpected issues that affect data quality, and therefore do not require any factoring to determine annual pedestrian volumes. Short-duration counts, however, represent a snapshot in time that may not be reflective of typical pedestrian activity levels, and therefore need to be factored in order to provide a reasonable estimate of annual volumes. We discuss concepts of temporal variation in the next section.

Temporal Variation

To better reflect true AADP, short term counts must be adjusted to account for typical variations that occur throughout the day and year. Hour of day, day of week, and month of year are typical periods for which adjustment factors are created.

Hour-of-day

Just as with motor vehicle traffic, pedestrian traffic varies greatly throughout the day. Peak volumes often occur in mornings and late afternoons. Lunchtime peaks are also common. Consequently, to accurately translate hourly counts to daily volumes, representative hour of day patterns must be established then applied to hourly counts.

Day-of-week

Similarly, pedestrian travel patterns vary greatly between weekends and weekdays. To estimate AADP, longer counts (one week or more) are needed to identify the variances among various days of the week so that they can be applied to calculated daily volumes. Day-of-week adjustment factors are calculated as the AADP divided by the average traffic occurring on a particular day of week throughout the year. This is frequently approximated by dividing the average daily pedestrian traffic for one week of counts by the relevant daily count for a given day of week. However, as weekly patterns can change dramatically with the seasons, this approach can yield inaccurate AADP if applied to a daily count that was conducted during a month or season outside of the period used to create the adjustment factor. For pedestrian volumes, seasonal day-of-week factors are preferable to a single a day-of-week factor.

Month-of-year

Monthly (seasonal) variations must also be accounted for when translating short term counts into AADPs. This is particularly important in places where temperature and precipitation levels vary between seasons. Continuous count stations or a sufficient amount of weekly counts to compare volumes across months are essential for determining monthly variation throughout the year. Monthly adjustment factors are calculated as the AADP divided by average pedestrian traffic over a particular month.

Temporal Adjustment Factors and Factor Pattern Groups

Temporal adjustment factors are created (ideally) from continuous counts. The first step is to translate the hourly (or multi-hourly) counts into daily volumes. This is done by dividing the counted volume by the percentage of the daily pedestrian volume typically occurring in the counted period. The AADP can then be calculated using the equation

$$AADP = PedV * DOW * MOY$$

Where

PedV = Daily pedestrian volume for day counted

DOW = Day-of-week adjustment factor

MOY = Month-of-year adjustment factor

Factor groups are groups of continuous count stations with similar traffic patterns used to compute the temporal adjustment factors, defined above, which can be applied to short-duration counts to estimate AADP. Each factor group within a counting program has an associated set of temporal adjustment factors derived from the variability observed at the sites within the group. As the number of factor groups and the number of continuous count stations used to estimate factors both increase, it becomes possible to specify a more precise factor group for a given short-duration count, and the accuracy of count extrapolation improves. For motor vehicles, factor groups are frequently based on roadway functional classification and area type. Similar characteristics can also be used in developing pedestrian factor groups, but facility type (e.g., roadway versus shared use path) and predominant user type (e.g., commuters versus recreational users) are more likely to be defining traits. The TMG formats offer storage of the associated factors used for pedestrian counts for reference and later use.

Other Considerations

Weather

Weather is another factor that should be considered when extrapolating short term counts to AADP. There is no method routinely used to create weather factors for calculating AADP. However, there have been several research studies indicating the importance of weather on pedestrian travel behavior.[106,107]

Data from count stations could be correlated with variables such as temperature using readily available historic data. Factors such as rain and snow, however, are more problematic since precipitation levels are more temporally and geographically localized than temperatures. Additionally, a light afternoon sprinkle likely will not impact volumes as much as a more intense rainfall.

Manual counts are often conducted under relatively clement conditions and thus represent seasonal ideal conditions instead of average conditions. Therefore, AADP calculated from short term manual counts will over-represent the true AADP unless weather conditions are considered. Consequently, local ideal-to-average adjustment factors may be advisable, but these would likely need to be determined through special examinations of historical counts. National weather station data together with locally recorded weather should be considered part of a pedestrian counting program to account for the effects of weather. Keeping the weather data with the count as is done with the TMG nonmotorized format offers significant advantages to the long term utilization of the pedestrian count.

Occlusion

Occlusion adjustment factors (a type of bias compensation factor) are used to account for multiple pedestrians traveling in groups and/or side by side being under counted. Bias compensation factors for occlusion can be calculated by dividing the pedestrians counted using manual counts by the number counted by the installed equipment. These factors should be determined for each site or group for a count program.

Chapter 4 of NCHRP 797 provides detailed information on creating and applying occlusion and other bias compensation factors, including typical factors by equipment type and how to apply these factors.[108] This includes how to apply non-linear bias compensation factors for passive infrared counters for which occlusion increases with increasing pedestrian volume. This chapter also mentions how equipment error (and hence equipment-related bias compensation factors) may vary by weather.

STATE OF THE PRACTICE

As noted in the introduction, the field of pedestrian traffic counting is relatively new; as such, the state of the practice is evolving and somewhat limited. Two primary resources that include guidance related to pedestrian count durations and factoring processes have been published since 2013, the updated TMG[109] and NCHRP Report 797: Guidebook on Pedestrian and Bicycle Volume Data Collection.[110] We summarize these resources, as well as recent relevant research, in this section.

Traffic Monitoring Guide

The FHWA TMG 2013 Chapter 4 is a stand-alone chapter on the subject of traffic counting for nonmotorized traffic. In addition to discussion and recommendations related to nonmotorized count equipment and count locations, this chapter devotes significant attention to variations in pedestrian and bicycle travel patterns, associated impacts on appropriate duration of counts, and resulting processes by which to factor short-duration counts into accurate estimates of annual travel.

The TMG states that "There is no definitive guidance on the minimum required duration of short-duration counts"[111] for nonmotorized counts. Despite this general condition, the TMG does establish recommended minimum durations depending on the technology being used. For manual counts, the TMG suggests a minimum duration of 4 to 6 hours, preferably during a time of relatively heavy nonmotorized travel, with a preferred duration of 12 hours, which permits the calculation of time-of-day profiles.[112] Recognizing the resource limitations associated with manual counting, the TMG acknowledges that two-hour counts (still the prevailing practice) are better than nothing, but recommends instead conducting fewer counts for longer periods.[113] When automated count equipment is being used, the TMG-suggested minimum count duration is 7 days to account for all days of the week, with a preferred duration of as long as 14 days.[114]

The TMG suggests that counts conducted during months of the year associated with "average or typical" activity levels, ideally as determined by data from continuous counters, may not need factoring; otherwise, a factoring process is needed to adjust short-duration counts to better represent annualized counts.[115] The TMG identifies up to five factors that may need to be applied to short-duration count data to achieve an accurate annual estimate: time of day (if less than a full day of data), day of week (if less than a full week of data), month/season of year, occlusion (depending on automated equipment type), and weather.[116]

For motorized traffic data, the TMG identifies recommended factor groups based on area type, roadway functional class, and predominant trip purpose.[117] Each factor group established within a traffic counting program consists of locations where continuous counts are conducted and has a defined set of temporal adjustment factors. Each short-duration count is assigned to the most representative factor group for best approximating temporal adjustments to the collected data. Regarding nonmotorized traffic data, the TMG acknowledges a lack of consensus on the appropriate number of continuous counts to comprise a factor group and the appropriate number and character of the factor groups themselves, as well as the fact that very few agencies are using factor groups for nonmotorized counts.[118] It expresses a hope that future editions of the TMG will be able to recommend additional guidance on this topic, and such guidance is now available from NCHRP Report 797 and other recent sources.

NCHRP Report 797

NCHRP Report 797: *Guidebook on Pedestrian and Bicycle Volume Data Collection*, published in 2014, a year after the most recent edition of the TMG, includes recommendations related to count duration, count frequency, and temporal adjustment factors, much of which is based on research published shortly after the finalization of the TMG.

NCHRP 797 notes that the appropriate count duration depends significantly on the purpose of the count data; for example, an agency interested in determining hourly volume patterns does not need to collect data for as long as an agency trying to determine seasonal variation.[119] As with the TMG, NCHRP 797 acknowledges that short-duration counts of at least two hours can be extrapolated to longer periods, but that doing so has the potential to introduce significant error. That error is reduced as durations increase. Citing three recent studies, NCHRP 797 suggests that counts should be taken for four to seven days, and that extrapolation errors are further reduced when counts are conducted during seasons of relatively high activity.[120]

NCHRP 797 acknowledges that shorter-than-recommended bicycle and pedestrian counts can still be useful for certain objectives, including the ability to track trends over time.[121] If partial day counts are conducted, extrapolation accuracy can be improved by counting during several different time periods.

On the subject of count frequency, NCHRP 797 references the TMG's motor vehicle guidance to conduct short-duration counts such that the entire system is covered over a time period no longer than six years, with more important locations having a shorter coverage period of three years. NCHRP 797 goes on to state that "Communities should choose a frequency for pedestrian and bicycle counts that allows those communities to achieve their counting purpose with the available resources."[122]

As with the TMG, NCHRP 797 emphasizes the importance of developing temporal adjustment factors based on continuously monitored sites. The guidebook acknowledges that an ideal number of continuous count stations has not been identified, but cites the TMG recommendation of three to five such stations per factor group.[123]

Additional Resources

One of the earliest efforts to promote nonmotorized traffic counting and to standardize its practice is the National Bicycle and Pedestrian Documentation Project (NBPDP), which began in 2004 and remains active. The project is designed to provide a consistent model of data collection by providing standardized instructions, forms, and data entry templates for use by agencies conducting counts.[124] The NBPDP also provides standard count dates and times, receives all collected data, and makes the resulting findings publicly available. NBPDP count sites are generally consistent from year to year.

In a 2013 paper*,* Nordback et al. tested numerous short-duration count durations to determine their accuracy in estimating annual average bicycle travel.[125] This was done by applying temporal adjustment factors (taken from two factor groups comprised of multiple continuous count stations) to the various short-duration counts and comparing the resulting estimates to actual annual counts. The short-duration count lengths ranged from one hour, with an associated average error rate of 54 percent, to four weeks, with an average error rate of 15 percent. Given that the average error rate associated with one-week counts (22 percent) is not notably worse than with four-week counts, the study finds that one-week counts are optimal, and recommends a minimum count duration of 24 hours (38 percent error). The researchers also recommend that short-duration counts be conducted during time periods when travel variability is relatively low and that installation of multiple continuous counters is essential in establishing meaningful factor groups. While this research is specific to bicycle counting, the similar (and frequently somewhat higher) variability between pedestrian and bicycle travel suggests that the findings and recommendations are generally applicable to pedestrian counts.

Hankey et al. recently conducted a study on nonmotorized counting practices and corroborated the above study's recommendations on optimum duration and seasonal timing of short-duration counts to reduce error rates in estimating annual travel.[126] Additionally, the researchers propose the use of specific day-of-year adjustment factors as opposed to the more traditional application of both day-of-week and month-of-year factors. This approach is shown to further reduce estimation error but has inherent limitations, including the fact that day-of-year scaling factors are can only be used for the year in which they are calculated and can only be applied after the end of the calendar year once the reference continuous count sites have concluded their annual data collection. The researchers also conclude that there are no significant differences in error rates between short-duration counts conducted on consecutive days and those conducted on non-consecutive days.

While researching the effectiveness of several approaches to estimating annual bicycle travel, including a weather-based model, Nosal et al. also explored the topic of optimum count durations.[127] While results vary based on the estimation method, the researchers generally cite benefits of five days of data collection. As with Nordback et al., this research is specific to bicycle counts, but results are generally transferable to pedestrian travel counting.

STATE OF THE PRACTICE - KEY FINDINGS

Count Duration

The state of the practice has coalesced around the need to conduct short-duration pedestrian counts for a longer period of time than two hours, which is commonly used for manual counts. The widespread availability of portable automated counters that count pedestrians with relatively high accuracy has enabled many agencies to conduct counts for an entire day or longer, thereby eliminating the need for hour-of-day factoring and improving the accuracy of AADP estimates. In line with the findings of multiple recent studies, one week is recommended as the optimum pedestrian count duration, with a minimum duration of 24 hours.

In all likelihood, “traditional” (i.e., partial day manual) short-duration pedestrian counts will remain common because of a combination of existing practice, budget constraints, specific project needs, and the ability to collect age and sex information. In terms of factorability and potential uses, such counts are fundamentally different from the recommended short-duration counts that take place over the course of one day to several weeks. As such, the latter group can be considered “mid-length.” This concept is further discussed in the recommendations section of this chapter; additional research better distinguishing the characteristics and uses of these two count types may be beneficial.

The research indicates less consensus, or even discussion, regarding how frequently counts should be conducted at given locations. Much of this is due to the fact that the concept of a pedestrian count network is less defined than a motor vehicle count network. An agency may consider all arterial and collector roadways its motor vehicle count network, but for the pedestrian modes some of those streets may not be considered as important as shared use paths or local streets that experience heavy pedestrian travel. This situation is frequently compounded by the generally much smaller scale and budget of pedestrian counting programs, which makes it more difficult to count regularly across a larger network even if it is well defined. A synthesis of nationwide practice on the topic of establishing standardized pedestrian counting networks is a potential future research effort. Furthermore, research on short-duration count frequency to cover these networks would be appropriate. At a minimum, the TMG-recommended three- to six-year frequency for motor vehicle counts is warranted; if anything the more variable nature of pedestrian activity suggests that more frequent counts may be appropriate.

Factoring

As noted in the TMG, there is relative lack of study and consensus on the subject of factor groups for pedestrian counts, both in terms of the number and character of those groups. The importance of creating factor groups is widely acknowledged, as is the need to include multiple continuous count stations within each group. The TMG currently identifies a rule of thumb of three to five nonmotorized count stations per factor group,[128] and the TMG- recommended minimum of five stations per factor group for motor vehicle counts is also frequently cited as a default, but the point of diminishing returns has not been established. Locations or trip purpose (i.e., commute vs. non-commute) remain the most common distinction in creating factor groups. Additional distinctions, the efficacy of which could be the subject of future research, include subdividing non-commute routes into recreational and utilitarian, area type (urban, suburban, rural), and facility type (sidewalks, paved shoulders, shared use paths adjacent to roadways, shared use paths within their own rights-of-way). A funded FHWA research project, “Developing an Online Tool to Estimate Annual Average Daily Pedestrian and Bicycle Traffic,” is currently addressing this topic.

STRATEGIC CONSIDERATIONS FOR PEDESTRIAN COUNTING PROGRAMS - SUMMARY OF FINDINGS

Though a variety of count types, durations, locations, and technologies are necessary in order to collect valid and meaningful pedestrian data, the majority of pedestrian counts are still short-duration, two-hour manual counts. The best practices listed below will help to broaden the variety of pedestrian counts conducted and enhance the quality and usefulness of the data collected:

- Expand the use of “mid-range” (multi-day or multi-week) counts to reduce associated estimation error rates.
- Beware of the inherent pitfalls, primarily estimation inaccuracies, associated with partial day pedestrian counts.
- Rotate "mid-term" automated counter(s) around the network in order to determine what type of pattern exists at each site (commute, mixed, non-commute, etc.) and use the findings to choose the right set of adjustment factors (temporal, weather, etc.) and to adjust the time during which manual counts are conducted to match the actual peak hour.
- Use manual short-duration counts to validate results of mid-term and continuous counts.

Given that undercounting rates and resulting bias compensation factors are typically higher for pedestrian counts than with other modes, funding is needed for research that documents the error rates associated with various equipment types or develops broadly applicable bias compensation factors by equipment type, although some of these are documented in Chapter 4 of NCHRP 797.

5. DATA MANAGEMENT

INTRODUCTION

Managing data collected for pedestrians is critical to ensuring data availability, access, and proper usage. This section discusses four aspects of data management:

- Quality assurance and control
- Standard metadata
- Accessibility and distribution, including integrating pedestrian data with other datasets and collecting data from multiple entities
- Data analysis

Each of the following four subsections addresses one of these aspects, reviewing relevant resources, and summarizing findings. Two additional subsections provide detailed examples of count pedestrian data formats from:

- Vendor output from providers of pedestrian data, including examples from four different resources
- TMG station record and volume data

QUALITY ASSURANCE AND CONTROL

Overview

The level of quality of any dataset will limit the uses of that data. For example, data on pedestrian volume that is only accurate within an order of magnitude may be useful for planning and design purposes, but not for detailed safety analysis. For this reason, it is essential that the users understand the quality of pedestrian data. Though there is no exact guidance on the level of data quality needed for different applications, Table 5-1 shows guidelines for the recommended level of quality for different uses.

Table 5-1. Sufficient Data Quality by Purpose

Data Use	Sufficient Data Quality
Sketch planning, proposals	Low (within an order of magnitude)
Facility design, economic impact assessment	Medium
Safety analysis	High

This subsection reviews guidance and best practices in assessing, measuring, evaluating, and reporting data quality for pedestrian counting. The sources reviewed cover a variety of issues related to data quality and occasionally use varying terms when discussing these issues. We consider quality assurance and control to include:

- Identifying potential sources of error
- Verifying and calibrating equipment
- Validating data

Review of Resources

Traffic Monitoring Guide

The Federal Highway Administration's Traffic Monitoring Guide (TMG) provides a comprehensive and standard set of procedures for collecting and reporting traffic data. Though the TMG is focused on motor vehicle data, much of its guidance is also applicable to pedestrian data. According to the 2013 TMG there are eight dimensions of traffic data quality: accuracy, completeness (both temporal and spatial), validity, timeliness, coverage, accessibility, how the data are used, and format.[129]

The TMG recommends that transportation agencies establish their own quality assurance process for automatically collected data, and provides the following guidance:

- The equipment should be tested to ensure that its meets the required level of accuracy before being placed into service.
- The equipment performance should be validated periodically to ensure that it continues to perform as intended.
- The collected data should be routinely subjected to quality assurance tests.
- The data should be analyzed and then quickly and routinely supplied to users so that data quality concerns not caught by the primary data quality process can be quickly identified by users.
- A feedback process should be in place so that the traffic monitoring group responds quickly and effectively to feedback from users. [130]

Equipment calibration and validation is the most labor-intensive component of any quality assurance and control program, because it occurs on an ongoing basis. This is particularly true for pedestrian data; the TMG notes that since portable pedestrian counting equipment is not as accurate as motor vehicle counting equipment it is not generally used for validation, and recommends using manual counts from video for validating pedestrian data.[131] The TMG states that "on-site and in-office calibration and tracking of site information should occur regularly (daily, monthly, and annually as needed)"[132] and outlines the elements of a robust traffic monitoring calibration program; the elements that are relevant to pedestrian data include:

- Implementing software tools that help automate the process.
- Performing daily diligence activities such as business processes that ensure checking the quality of data as it is collected/processed/stored in the master (centralized or distributed) traffic database.
- Evaluating data using monthly trends and yearly trends to determine validity.
- Conducting field calibration.
- Collecting manual counts and comparing counts against portable equipment collected counts.
- Performing manual and electronic calibration of volume data and portable hardware annually.[133]

The TMG also includes case studies of motor vehicle data quality assurance and control programs from Virginia, Vermont, Pennsylvania, Washington State, and New York State that illustrate best practices. For example, Vermont includes monthly manual inspection of graphs of traffic over a 24 hour period from each day of the week for a given month to identify problems. Automated checks identify monthly volumes that are 10 percent different from the previous year.[134]

Appendix J of the TMG includes details of the Quality Control Checks for motor vehicle data used in the Travel Monitoring Analysis System (TMAS) 2.0 to identify potentially faulty data. There are four types of data flags: Fatal Errors, Critical Errors, Caution Flags and Warning Flags, which are defined as follows:

- **Fatal Errors** occur when the data are in the wrong format (e.g. an unexpected data type is encountered in a given column).
- **Critical Errors** occur when a field marked as "critical" in the TMG format is missing (left blank) in the input file. Critical errors for volume data also include:
  - 7 or more consecutive hours with zero volume
  - One day of the week is not represented in a month for a given site in a given year
  - Fewer than 24 hours for a given record
  - Volume is over the maximum threshold per lane
  - Directional splits greater than 10 percent variance from 50 percent
  - Monthly Average Daily Traffic (MADT) is not within 20 percent of previous year's MADT for that month
  - State marks data as "restricted"
- **Caution Flags** are used when the record is missing optional data or when odd or out of bound data are encountered. These include historical checks for a given day of week based on the previous 6 weeks for a given vehicle class. Caution flags are also used to indicate when there is insufficient historical data to run a test.
- **Warning Flags** are issued when exact duplicate records are submitted. One of the duplicates will be deleted. The user can abort or reject duplicate data.

National Highway Institute Course - Traffic Monitoring Programs: Guidance and Procedures

The National Highway Institute (NHI)[135] offers a class on traffic monitoring programs that highlights seven data quality principles:

1. Data quality is more than correcting data.
2. Data assessment identifies process improvements.
3. Quality control process check for valid data that are not necessarily accurate data.
4. Data needed to be useful, not just accurate.
5. Quality problems are not necessarily caused by people.
6. Inserted non-quality data doesn't improve quality.
7. Recounts and poor decisions are more costly than ensuring initial data quality.[136]

The NHI lists elements of a successful motorized and nonmotorized data quality program which include established procedures, installation protocols, annual equipment checks, equipment validation by comparison with manual counts, and automated flagging of errors in the data.[137]

The NHI course also classifies the many different elements of data quality assurance and control program, scope, and plan into four categories: data collection, data processing, implementation plan, and documentation.

Data collection involves equipment purchase, installation and maintenance, staff training on how to use the equipment, and verification that equipment is working properly from bench testing before equipment is deployed to daily quality checks in the office.

Data processing includes identifying obvious errors, from equipment malfunctions to data problems such as data sets with an unusual number of zero records, data that repeat previous data (which may indicate a time stamp error) or data that are inconsistent with historic counts at that location. Data processing can also include automated validation processes that identify missing data by hour, day and month or compare counts to historical counts at that location to counts at surrounding locations and to counts within the state and surrounding states. Another aspect of data processing is the creation of temporal adjustment factors from seasonal adjustment factors to annual growth trends (see Chapter 4 for a further discussion of adjustment factors), including hour-of-day, day-of-week, month-of-year, and year-by-year trends.

These data collection and processing tasks can be coordinated through an implementation plan that includes identifying resources, providing training for staff, defining who is responsible for what, and monitoring program progress. The last aspect of data quality discussed in the NHI class is documentation, which includes the flow of information on data quality within the agency and between agencies in order to meet data integrity goals. This can include communication between data collectors, data processors, and data users.[138]

Turner & Lasley

In a recent research paper, Shawn Turner and Philip Lasley of the Texas A&M Texas Transportation Institute examine data quality for pedestrian and bicycle count data. [139]

The authors stress that the acceptable level of data quality is determined by what it will be used for. They outline six aspects of data quality: accuracy, validity, completeness, timeliness, coverage, and accessibility. The authors choose to focus on accuracy and validity and leave the other topics for future research.

Two types of accuracy tests are discussed in the paper: controlled and field evaluations. Controlled evaluations are conducted in an environment where the behavior of those counted and the configuration of the counter is controlled by the investigator. For example, a controlled test may ask participants to walk side by side in order to study errors from occlusion. This helps understand specific potential sources of error. By contrast, field evaluations are conducted by observing facility users who are not being directed by the investigator. This helps understand accuracy in practice, where things the investigator did not foresee may occur.

The paper recommends three methods to check the validity of automated data: quality control checks, validity criteria, and business rules. Quality control checks include visual review. The authors focus primarily on automated validity criteria as the “first line of defense” in protecting against erroneous data. Validity criteria include:

- Upper and lower bounds for expected counts for a given time period.
- Comparisons with previous counts at a given location (historical counts) and other stations in the vicinity of the site as well as comparison of counts at the same site by direction for two-way facilities (the authors recommend less than 80 percent deviation between directions)
- Expected ratios of peak hour to daily volumes
- Technology-specific detailed diagnostics.

The authors examine an example data set from a trail in Texas. They use the first and third quartiles of hourly counts per direction for weekdays and separately for weekends to identify unusually high counts outside the interquartile range (IQR) represented as:

$IQR = 2.5\ (Q_3 - Q_1) + Q_3$

Where Q_1 and Q_3 are the first and third quartiles, respectively. A constant of 1.5 is more common for motor vehicles, but the authors they use the value 2.5 to be more "conservative." They also use counts in one direction to check and adjust counts that were unusually high in the opposite direction. They also highlight the importance of checking data manually through visual inspection.

NCHRP 797 Guidebook on Pedestrian and Bicycle Volume Data Collection

NCHRP 797, Guidebook on Pedestrian and Bicycle Volume Data Collection, discusses data quality issues for both manual and automated bicycle and pedestrian counts. For manual counts, the report stresses the importance of training volunteers or staff. For automated counts, the report lists the following sources of counter inaccuracy for automated counting technologies: occlusion, environmental conditions, counter bypassing, and mixed-traffic effects.

- Occlusion occurs when pedestrians pass a counter such that one pedestrian obscures the other from the counter's view.
- Environmental conditions mentioned include hot and cold temperatures, precipitation for thermal sensors, and precipitation and lighting for optical sensors. The report does not observe significant errors associated with these conditions for the situations and technologies studied. However, the report does reference a study by Andersen et al. (2014) that finds that people wearing heavily insulated clothing (such as a down parka in cold weather) were not counted by a passive infrared counter.
- Counter bypassing is a common source of error, especially for automated counters. This can occur if a pedestrian walks out side of the detection zone, for example.
- Mixed traffic effects may occur when pedestrians and bicycles use the same path.[140]

To understand and quantify error, the report recommends that each counter should be validated though an initial test of 15 minutes to one hour of counts during which an on-site manual count is compared to the counts on the automated counter. In addition, the report recommends that the first few days of counts at a new site should be examined for any strange patterns that may be due to unusual behaviors specific to that site, installation problems, or environmental issues. For example, infrared sensors can be sensitive to heat from surrounding sources, which may result in false pedestrian counts.

For continuous sites, the report recommends that the initial test be followed by a longer-term test that provides a basis for calibrating equipment. Some detection technologies may have different settings or allow adjustments that may improve the count accuracy. The report recommends working closely with the vendor to reduce inaccuracies. After these steps have been taken, remaining errors can be corrected by using a bias compensation factor computed based on the manual validation count. This bias compensation factor can correct for "systematic over- or undercounting associated with a particular counting technology."

Minnesota DOT Draft Bicycle and Pedestrian Data Collection Manual

The recently released draft of the Minnesota DOT (MNDOT) Bicycle and Pedestrian Data Collection Manual draws heavily from the 2013 TMG and NCHRP 797, but includes additional guidance on managing and analyzing pedestrian counts. The draft manual explains that there are two aspects to counter validation: "(1) confirmation of counter operations; and (2) identification and correction for systematic counter error. "[141] The manual recommends using two individuals to validate equipment, one to trigger the sensor and the other to watch the equipment. At higher volume locations, the extra person to trigger the sensor may not be needed if there is sufficient traffic to test the sensor. Like the TMG, MNDOT recommends validating continuous count stations at least annually.

MNDOT reports finding that traditional automated checks of continuous count data used for motor vehicles based on statistical tests to identify outliers, are not as useful for pedestrian traffic. This is because pedestrian traffic can be highly variable, especially in low traffic volume locations where hours of zero counts are common, but a track team out for a run can cause a sudden spike.

Literature on Manual Counting

Our review focuses on research related to automated data collection because it is the most efficient way to collect a sufficient amount of data for planning and analysis purposes, and because the automated counting equipment that is currently available tends to less accurately measure pedestrian traffic than manual counts. However, even in automated data collection programs, manual counts are often used to ground truth data, so the quality of manual counts should also be considered. For example, Diogenes et al. found that for manual counts at intersections with paper or clickers underestimated pedestrian volumes by eight to 25 percent, and that error was greater at the beginning and end of the count period.[142]

The TMG advises that because accuracy decreases for manual counters after two hours, counters should be given breaks.[143] Observer inattention is a source of error. Concerns are often expressed that volunteer counters may have ulterior motives which may lead to overcounting, but evidence of this was not found in the literature. To overcome these sources of error, manual pedestrian counts based on videos of facilities that can be reviewed in the office are commonly considered to produce the highest accuracy counts and are recommended when validating and calibrating counting equipment.

Current Practice

Because the field of pedestrian data collection is still evolving, we asked practitioners how they quality check their continuous count data. Currently, most nonmotorized traffic count data is bicycle data. Because bicycle and pedestrian count data are often collected in the same data stream, both are often processed in the same way by many practitioners. These data streams can be either combined bicycle and pedestrian counts, such as from a passive infrared counter, or separated bicycle and pedestrian counts from a combined inductive loop with infrared counters, such as the Eco-Multi. Findings below are for jurisdictions who have counting equipment which separates pedestrian from bicycle counts:

- Craig Moore, who manages the Seattle Department of Transportation (SDOT) bicycle and pedestrian count program, reported that SDOT looks for missing data or abnormally high values that are three standard deviations above values from adjacent days.[144]
- Greg Lindsey, professor at the University of Minnesota, has been examining data cleaning procedures with his students. He has observed that the validation checks that are designed for higher volume sites are not always useful at low volume sites because of high levels of variation in results.[145] They are applying the criteria they develop to assist the Rails-To-Trails Conservancy in their weekly data quality checks of bicycle and pedestrian count data. Dr. Lindsey mentioned that they are experimenting with data cleaning by removing data beyond two or three standard deviations from the average and recalculating annual averages to see if they are substantially different without the outliers.
- Ken Brubaker at Colorado Department of Transportation has developed a set of criteria which he applies to their bicycle and pedestrian count data (only five sites count pedestrians

separately) including checks for consecutive zeros, data gaps, comparison to previous year's data (flag data two to two and a half times higher than the estimate), and directional distribution check (directional splits greater than 70 percent/30 percent are considered suspect)[146].

- Sarah O'Brien at North Carolina State's Institute for Transportation Research and Education (ITRE) reports in the webinar sharing document that their continuous count pedestrian data go through "range check, directional distribution check, empty data check, consecutive zero check." They test for data gaps (hours with blank count data). They also check for over three days of consecutive zeros, and directional splits over three standard deviations from the average directional split. Their range check is based on a model of daily counts for each site based on the last 6 months of cleaned data which includes temperature, precipitation and day of the week. If the difference between the actual daily and predicted daily count is outside of three standard deviations, the data are flagged.[147]

In addition, some quality checks have been developed for bicycle data, which may or may not be relevant for pedestrian data:

- Josh Roll, transportation and land use modeler for Lane Council of Governments (LCOG), manages their bicycle count program. He reported experimenting with identifying suspect bicycle count data through an iterative automated process that removes data beyond a given number of standard deviations from the average and then recalculates the average and standard deviation without the outliers and repeats the process. LCOG is in studying how this procedure could be used to identify potential outliers in their data. While this approach has been developed for bicycle count data, it may also be applicable to pedestrian data.[148]
- Krista Nordback at Portland State University is examining how to create automated validation criteria for Bike-Ped Portal, Portland State University's nonmotorized traffic count data archive. She examined bicycle count data and found that it's rare to see more than 15 consecutive hours of zero counts or more than six identical non-zero values, and that 1,500 counts per hour or 5,000 counts per day are good upper bounds for the majority of facilities. Pedestrian data may have much higher maximum volumes as illustrated by high counts reported in New York City.

In addition, FHWA is proposing the following checks for all nonmotorized traffic data to be utilized as part of the Travel Monitoring Analysis System (TMAS) version 2.7, including pedestrian data:

- Adjacent intervals: If the count in the interval being evaluated is less than 100, flag it if it is 100 percent over or under the count for the previous interval. If the count in the interval being evaluated is 100 or more, flag it if it is plus or minus 100 higher or lower than the previous interval count.
- Consecutive zeros: If the counts are in hour intervals, check that there are no more than 7 consecutive hours with zero values. Counts of intervals smaller than one hour would be aggregated before this check is performed.
- Total daily count: Flag the data if the total daily count exceeds 50,000.
- Total hourly count: Flag the data if the total hourly count exceeds 4,000.
- Identical counts: Flag intervals when there are more than three identical adjacent non-zero values.
- Historical data: To evaluate the count on a given day, average the daily totals for the past six weeks for a given day of the week at a given location. If the total count for the given day to be evaluated is less than 1,000, flag the day if the average for the previous six weeks for that

day of the week is 100 percent higher or 100 percent lower than the daily total being evaluated. If the daily total is 1000 or more, flag the day if it is not within the interval plus or minus 1000 of the average computed from the past six weeks for that day of the week.

In TMAS, these quality control flags are to be changeable so that values that reflect travel patterns specific to that count location can be used instead of the default values. These local QC criteria would then be stored for future counts done at the same location.

Some vendors of pedestrian count data collection devices also build in the capability to conduct automated data quality checks. For example, Eco-Counter's Eco-Visio software reports the following flags for continuous sites with automatic data uploads:

- No Data Transmitted: This indicates that the daily upload of data failed.
- Zero Counts: This indicates that the sum of counts over a 24-hour period is zero.
- Maximum Exceeded: This indicates that a predetermined maximum value has been exceeded.
- Large Variation: This indicates data which deviates from average of the previous "four last similar weekdays" by a set maximum percent variation either over or under the average. The flag provides an indication of the magnitude of the percent difference from average, the average, and whether the day's count in question was lower or higher than average. Variations larger than 50 percent are often flagged.

Similarly DataNet, TRAFx's proprietary software allows users to flag the ten highest days as possible outliers.

Quality Assurance - Findings

There are multiple aspects to quality checking of traffic data in general, many of which apply to pedestrian data:

- Verifying and calibration of the counting technology by manual ground truth counts.
- Data format checks.
- Data validity criteria for automated checks.
- Manual data validity inspection.

NCHRP 797 outlines a validation process for automated counters that involves comparing automated count to manual count data using short-duration tests for all sites and long-term tests for continuous sites. The test for long-term sites include comparing counts from the automated equipment to ground truth counts collected by manually counting pedestrians from recorded video or in the field for a 15-minute to two-hour time period.[149] The report recommends that this should be done at installation, several days after installation and annually thereafter. In addition to the comparison of ground truth manual counts to automated counts, it also recommends visual inspection of the travel pattern observed in the first days after counter installation in order to observe any unusual patterns that may be associated with other modes inadvertently being counted.

There are currently no standard procedures for automated checks of pedestrian continuous count data. This is an area of continuing research. Some automated quality assurance and control procedures include checks for multiple days or hours with consecutive zeros, missing data, repeating counts, comparison to previous counts, and checks for spikes above some threshold. Current practice is summarized in Table 5-2.

Table 5-2. Summary of Quality Control Checks for Non-motorized Traffic Counts

Source	Upper bound [lower bound]	Identical non-zero values	Consecutive zeros	Directional Split
Turner & Lasley	Interquartile range (IQR) = 2.5 (Q_3-Q_1) + Q_3	-	-	-
Seattle Department of Transportation	3 standard deviations above surrounding days	-	-	-
University of Minnesota	2 to 3 standard deviation above average	-	-	-
Colorado Department of Transportation	Weekly check: daily count 3 times higher previous year's average daily traffic; Quarterly check: IQR = 2.5 (Q_3-Q_1) + Q_3	-	Over 2 days of zero counts (non-mountain locations)	splits greater than 70 percent/30 percent
North Carolina State University	3 standard deviations above [or below] predicted daily count based on model from previous 6 months of cleaned data (model includes weather and day of week)	-	Over 3 days of zero counts	Splits greater than 3 standard deviations of average
Portland State University	1,500 per hour, 5,000 per day	Over 6 identical non-zero values	Over 15 hours of zero counts	-
FHWA TMAS V2.7	For hourly counts <100: flag if 100% over [or under] the previous interval count For hourly counts >100: Flag if 100 higher [or lower] than previous interval count Over 50,000 daily count; over 4,000 hourly count For daily counts under 1,000: Flag if 100% > [or <] than average of past 6 previous. If daily count over 1,000: flag if 1000 over [or under] the average of past 6 previous.	Over 3 identical non-zero values	<7 hours with consecutive zeros	-

Note: "-" indicates that no specific values were indicated for these tests.

METADATA STANDARDIZATION

Overview

In order to understand any travel monitoring data, it is necessary to know the basic who, what, where and how of the data: who collected it, what it monitors, where it was collected, and how it was collected. This is recorded in the metadata. Metadata allow data users to search for data by site or equipment characteristics and overlay data from different databases. For example if pedestrian volumes at crosswalks are desired for a safety study, the metadata allows researchers to identify the sites of interest and to match these sites with crash locations.

The TMG discusses standard metadata for motor vehicle travel monitoring as well as critical and optional metadata for nonmotorized traffic. Other community-used nonmotorized traffic datasets include different metadata.

This subsection discusses the most frequently documented metadata standards for nonmotorized traffic, including the TMG and the National Bicycle and Pedestrian Documentation Project, as well as standards used by local and regional governments that have extensive pedestrian data collection programs and those used in proprietary datasets such as Eco-Visio and DataNet.

Review of Standard Data Formats

Nonmotorized counting has only been widely practiced for a decade, meaning that the state of the practice is now where the motorized state of the practice was many decades ago. As such, data formats and standard metadata are still evolving, and vary widely among different sources. There are three significant national efforts to standardize pedestrian data collection: the National Bicycle and Pedestrian Documentation Project (NBPDP), the TMG, and Portland State University's Bike-Ped Portal. Standard regional formats include the Los Angeles Bike Count Data Clearinghouse (Huff and Brozen 2014) and the format used by the Delaware Valley Regional Planning Commission (DVRPC). Other data collection resources focus on specific facilities, such as the Rails-to-Trails Conservancy Trail Modeling and Assessment Platform (T-MAP), which is designed for trail planning data. Vendors also establish standard metadata for use by their clients as part of their proprietary software. Outside the US, Sustrans in the UK and France's national database of nonmotorized count data also have standard formats.

There are significant differences among the sources discussed above: some are designed for manual counts and some are designed for automated counts; some are designed to inventory infrastructure as well as count data. We focused our review on count-related metadata used in national resources or well-established local and regional resources from within the U.S.

National Bicycle and Pedestrian Documentation Project

The NBPDP accepts and stores data files submitted by email to the project's administrators. It encourages submitters to use its standard data format for such submission but does not require it. The format includes contact information for the person responsible for data as well as data fields summarized in Table 5-3.

The format asks for general information on the area in which the count is collected, location-specific information such as density and nearby land uses, and count data. While the location-specific information can be helpful in understanding the relationship between land use patterns and pedestrian behavior, data are often not easy for participants to collect, and data providers often skip submitting these data. The recent growth of national land use data sources such as the EPA Smart Location Database may eliminate the need for NBPDP data providers to submit this data.

NBPDP data is not accessible to the public and is not currently archived in a database. Access to NBPDP data is by request, and data are only available in paper format.

Traffic Monitoring Guide

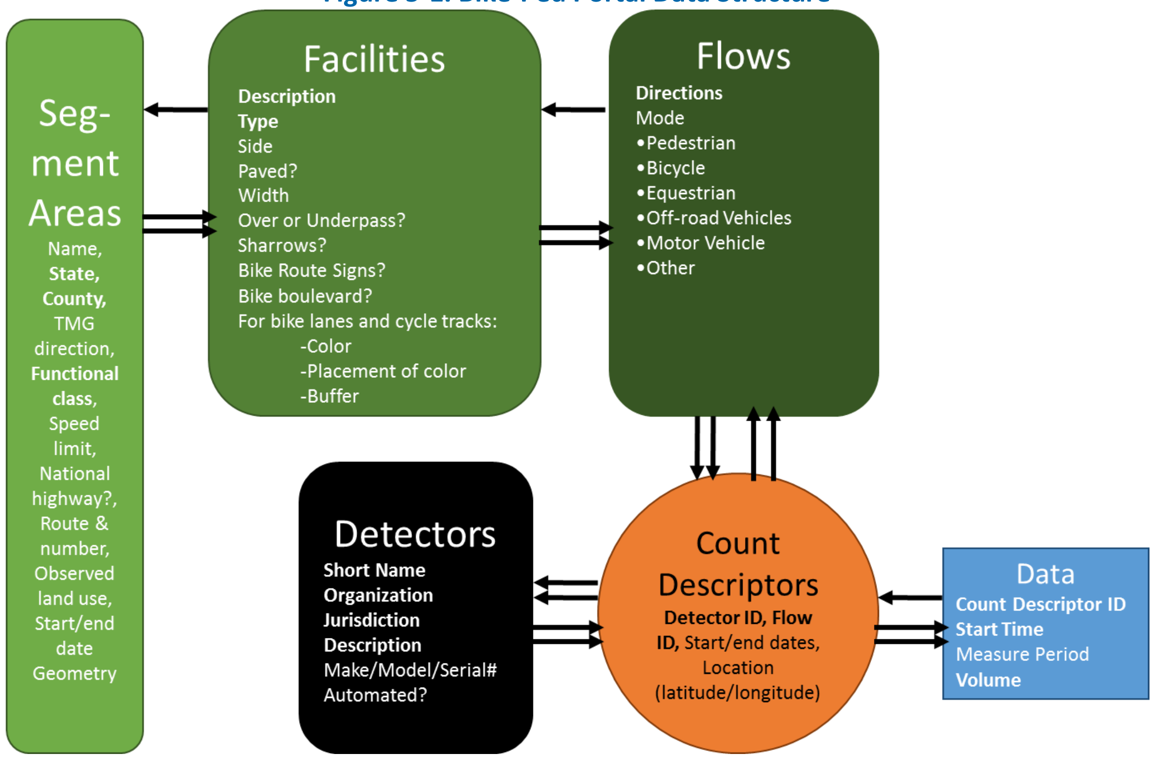
The FHWA TMG is “intended to provide the most up to date guidance to State highway agencies in the policies, standards, procedures, and equipment typically used in a traffic monitoring program.”[150] Chapter 7 of the recently updated TMG contains a format for coding, entering and sharing nonmotorized traffic count data. Unlike the other data formats discussed here, the TMG format has precise requirements for the number and type of characters in each field in a data file as discussed in the TMG Station Record Data and Volume Data subsection.

The TMG format includes two types of nonmotorized data files: station description records and count records. The station description record includes metadata about the station such as state and county codes, station identification code, functional classification of road along which the station is located (including two new categories for trails and general area counts). Each count record includes count data from a given time period (can be used for both portable and continuous count sites) less than 24-hours, organized by time interval, as well as metadata. Some of the metadata is repeated from the station file, while other metadata, such as optional weather information, a repeat some of this metadata and including the counts for each time interval. The count record includes data for a time period no longer than 24 hours per record, optional weather information, and repeats some of the same fields also included in the station description. When data are recorded for more than one day numerous records for the site would be recorded and stored for the TMG nonmotorized formats. Table 5-3 summarizes the metadata used in the TMG.

Bike-Ped Portal

The National Institute for Transportation and Communities (NITC), a federally funded University transportation Center at Portland State University, is creating a national online nonmotorized traffic count archive that includes pedestrian data in order to enable sharing of nonmotorized data. The archive is called Bike-Ped Portal and is being created as a part of an existing motor-vehicle data archive, Portal. The archive structure is designed to be able to handle both mobile and continuous counters as well as both automated and manual counts, and supports multiple counts of the same traffic flow. Currently it can only handle counts on road or path segments, not intersection counts, but NITC plans to expand the database to cover intersection counts. Figure 5-1 illustrates the basic data structure and metadata; Bike-Ped Portal metadata are also summarized in Table 5-3.

Figure 5-1. Bike-Ped Portal Data Structure



UC Berkeley SafeTREC Database

SafeTREC is a research center at the University of California, Berkeley, focused on transportation safety. SafeTREC maintains a database that inventories infrastructure as well as including nonmotorized traffic volume counts, and includes both a facility inventory and volume data.[151] For this reason, it has the most exhaustive list of metadata related to pedestrian infrastructure of any of the databases reviewed. The volume database can store both intersection and segment pedestrian count data, and includes metadata such as whether the count is on an intersection approach or in a crosswalk, whether the count is manual or automated, the approach ID or for crosswalks, the node and approach IDs, the volume by direction of travel, duration of count, start time and weather as a text description.

Los Angeles County Bike Count Data Clearinghouse

The University of California Los Angeles (UCLA) Luskin School of Public Affairs' Bike Count Data Clearinghouse project began in 2012 with the goal of housing bike volume data from the Los Angeles County region; the clearinghouse also includes pedestrian data. The project is co-sponsored by Southern California Association of Governments and the Los Angeles County Metropolitan Transportation Authority. This data archive offers a user-friendly interface featuring a web-based GIS tool to make data accessible for use. Data are standardized for municipalities in Los Angeles County. To our knowledge, this archive is the only publicly available publicly owned, online bicycle count archive that also enables no-cost online data uploads. However, data handling and uploading of data are restricted, and data suppliers must first obtain approval to upload data to the system.

The project database structure is focused primarily on handling data from two-hour manual counts. With a lack of continuous count volume data, users cannot draw conclusions about time of day, day of week, and travel volume trend patterns. However, the Bike Count Data Clearinghouse is the most extensive local data source that we reviewed, and we summarize the metadata used in Table 5-3

Other Public Datasets

Many other states and regions have standard policies for manually collecting pedestrian data, often influenced by the NBPDP. We summarize a few of the more longstanding examples below. Since these are not online resources, information about the exact format of data is not always available, and there is no distinction between mandatory and optional fields.

Washington State Department of Transportation (WSDOT) has a statewide pedestrian and bicycle data collection program where it facilitates annual manual counts in cities and counties. The documentation project has been ongoing since 2008, when it started with 19 communities, and has expanded to over 200 intersections in 39 different jurisdictions in 2013.[152] Each of the 2013 counts captured the number of bicyclists and pedestrians that passed through the intersection and the direction that each was heading when they left the intersection.

Minnesota Department of Transportation (MNDOT) has created a standard format for manually-collected pedestrian data but does not yet maintain a data archive.[153] The format includes standard metadata categorizing pedestrians according to the following characteristics: gender, adult/child, assisted/non-assisted ("assisted" includes wheelchair users and skaters). Other standard metadata include location (street or intersection); city and county; name, phone, and email of data collector; name, phone, and email of the agency managing the count; weather (precipitation and high/low temperatures); and latitude and longitude.

Other Private Datasets

In addition, some pedestrian equipment vendors maintain data for their clients in large databases that allow access to clients through online services. Two prominent examples are Eco-Counter's Eco-Visio service and TRAFx's DataNet service. A partial list of metadata collected by each are listed below.

- **Eco-Visio**: Name, setup date, serial number, latitude/longitude, photo, comment, description, time interval (15 min or 1 hour), mode of travel counted (bicycle, pedestrian, etc.), battery life, battery voltage, firmware version, and other information relating to automated data retrieval

- **DataNet**: Name, date on which counts were initiated, serial number, latitude/longitude, 2 photos, mode (infrared), data type (total hours), comments, battery voltage, firmware version, start and end date, adjustment factor, division by 2 (yes/no), and other counter-specific information.

Metadata - Findings

Table 5-3 summarizes the metadata fields used in five of the most widely-used or up-to-date formats discussed above. Required data fields are italicized.

Table 5-3. Summary of Metadata Fields Included in Standard Data Formats

Field type	NBPDP	TMG	Los Angeles	SafeTREC	Bike-Ped Portal
Identi-fication	▪ Location Description	▪ *Station ID*	▪ Location ID ▪ Dataset name	▪ Node Name ▪ Approach from and to Nodes	▪ *Segment Area Name*
Location	▪ Land uses ▪ Jurisdiction ▪ Population density ▪ Bike/pedestrian mode share ▪ Median age ▪ Median income ▪ Number of visitors ▪ Type of setting ▪ Scenic quality ▪ Visitor destinations	▪ *State* ▪ *County* ▪ Station Location	▪ Land use	None	▪ Observed land use ▪ *State* ▪ *County*
Route	▪ Posted speed limit ▪ Motor traffic volumes Intersecting traffic volume ▪ Crossing protection ▪ Route information ▪ Topography	▪ *Functional class* ▪ National highway ▪ *Direction of route* ▪ *Location of count relative to roadway* ▪ Posted speed limit ▪ Intersection ▪ Crosswalk ▪ Route signing, route number	▪ Road class ▪ Speed limit	▪ Transit stops	▪ *Functional class* ▪ National highway ▪ Side of road ▪ Speed limit ▪ Route signing ▪ Route number
Facility	▪ Facility type ▪ Length of facility	▪ Exclusive facility ▪ Sidewalk	▪ Type of other users	▪ Crosswalk style ▪ Curb ramp type Detectable warning surface color ▪ Color ▪ Ped signal head ▪ Ped call ▪ Safety island width ▪ Condition ▪ Sidewalk width Obstruction crossing distance	▪ *Description* ▪ *Facility type* ▪ Underpass ▪ Overpass ▪ Facility width ▪ Paved ▪ Buffer ▪ Pavement color ▪ Bike route signs present ▪ Sharrows present
Network	▪ Connecting facility quality ▪ Quality of network	▪ *Location of count relative to roadway orientation*	▪ None	▪ Connecting node, approach ID	▪ None
Counter	▪ None	▪ *Year established* ▪ Year discontinued ▪ *Latitude* ▪ *Longitude* ▪ Type of sensor	▪ None	▪ Manual / automated	▪ Latitude ▪ Longitude ▪ *Short name* ▪ *Description* ▪ Serial Number

Field type	NBPDP	TMG	Los Angeles	SafeTREC	Bike-Ped Portal
		▪ Linear Referencing System (LRS) ID ▪ LRS location point ▪ Station location ▪ Location relative to road			▪ Make ▪ Model ▪ *Owner* ▪ *Operator*
Count type	▪ None	▪ Count type (e.g., pedestrian, bike, both) ▪ Direction of travel ▪ Method of counting ▪ Factor groups ▪ Count purpose ▪ Notes	▪ Count method ▪ Direction	▪ Pedestrian / bicycle ▪ Direction	▪ Flow type (e.g., pedestrian, bike, both) ▪ Flow Direction
Date and time	▪ Date ▪ Time	▪ Year ▪ Month ▪ Day ▪ Count start time ▪ Count interval	▪ Date ▪ Day ▪ Period ▪ Interval begin	▪ Start date ▪ Start time ▪ Duration of count	▪ Start date ▪ Start time ▪ *Duration* ▪ *End date* ▪ *End time*
Weather	▪ Weather	▪ Precipitation ▪ High temperature ▪ Low temperature	▪ Raining	▪ Description of weather	▪ None
Factor Grouping	▪ None	▪ Five optional groups	▪ None	▪ None	▪ None

Table 5-3 illustrates just how varied data formats are. Users are presented with a large array of optional fields, many of which can be labor-intensive to collect. Some types of fields are frequently found in many of the archives, and serve as *de facto* high-priority variables. Below is a list of document data fields with the relevant TMG field names given in parenthesis.

- Station location, a text field describing the count location, include roadway name (Station Location)
- Station number, in format used by collecting agency (Station ID)
- Pedestrian facility type (Crosswalk, Sidewalk, or Exclusive Facility)
- Latitude and longitude (Latitude, Longitude)
- Direction of pedestrian travel (Direction of travel)
- Mode of travel (Type of count)
- Weather (Precipitation, High temperature, Low Temperature)
- Start date and time (Year of Count, Month of Count, Day of Count, Count Start Time for This Record)
- Count interval (Count Interval Being Reported)

Including the year in which the count site is established (Year Established) may also be a very helpful metadata field.

ACCESSIBILITY AND DISTRIBUTION

Overview

Sharing pedestrian data greatly increases its usefulness. The TMG encourages agencies to make data available to others: "Considerable benefit can be obtained by sharing these data collection resources. Access to additional counts will provide data for quality assurance, filling of count gaps, saving money and ease of reporting because all data can be integrated into one platform."[154] The FHWA allows all data in the Travel Monitoring Analysis System (TMAS) to be available to all users to facilitate data sharing between local agencies, metropolitan planning organizations, or states.

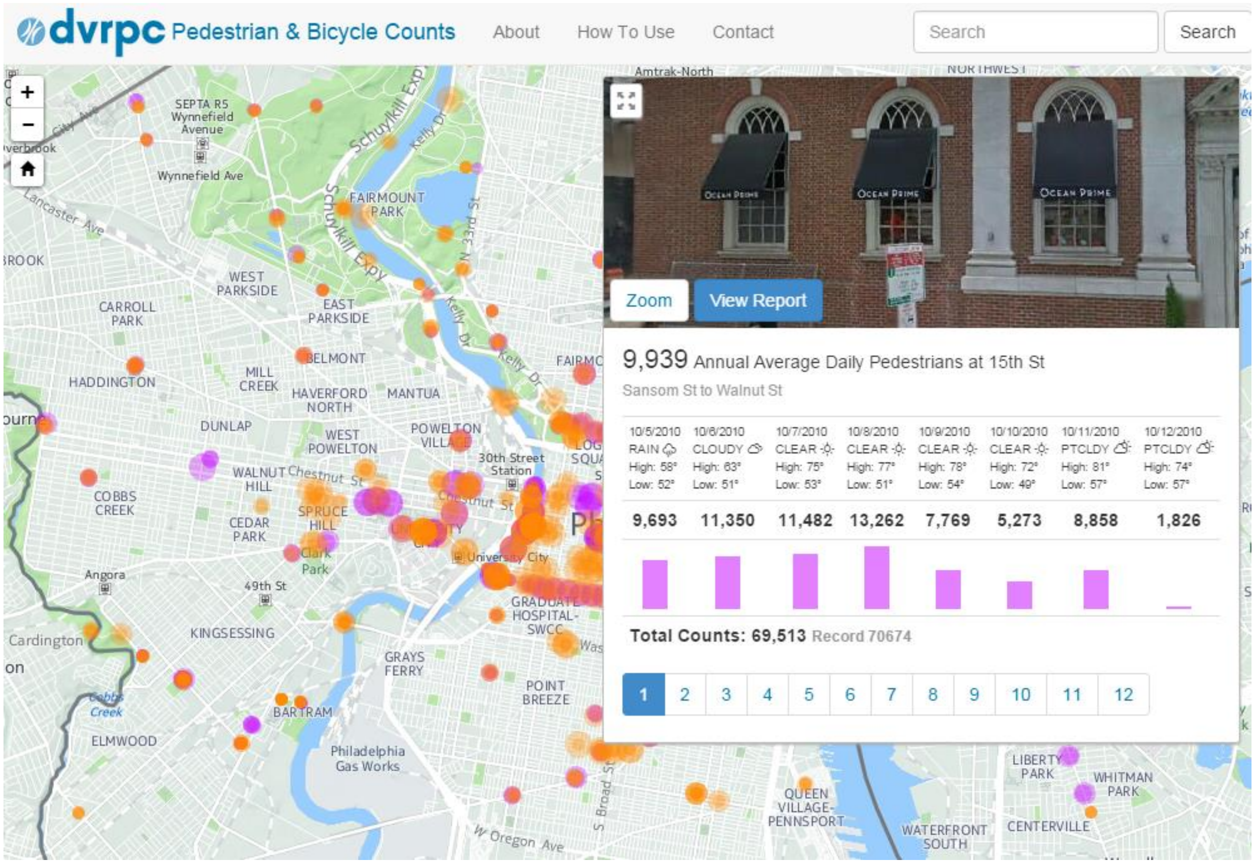
Once data are checked and loaded into a database with a standard format and metadata, they can be readily shared online. Two factors influence access to online data: whether the site hosting the data is owned and maintained by a public agency or a private company, and whether the data is publicly available to all users or whether access is limited. We focus our review on publicly owned and publicly available datasets, which allow the highest degree of accessibility and data distribution, but two publicly owned, password protected, sites are also discussed.

Review of Resources

There are relatively few publicly owned, publicly available resources for pedestrian count data. We reviewed the most prominent examples with which we are familiar. These represent some of the agencies who are more advanced in data sharing.

Delaware Valley Regional Planning Commission (DVRPC) Pedestrian and Bicycle Counts site[155] provides information on weeklong bicycle and pedestrian counts conducted on street segments throughout greater Philadelphia. Users can view a map with points showing the locations of different counts, color-coded by mode, and click on points to see details on the data collected through that count. Figure 5-2 shows an example of the map and reports produced through the site.

Figure 5-2. DVRPC Pedestrian and Bicycle Counts Website



BikeArlington Bicycle and Pedestrian Counters Website[156]. Bike Arlington, together with Arlington County in Virginia, hosts a site where count data from continuous pedestrian and bicycle counters are displayed. The site features the ability to both download and do simple analysis tasks including compare weather events and temperatures to count data. The site features a map of count sites and allows users to graph pedestrian data, filter it, and summarize the desired data (Figure 5-3 and Figure 5-4).

Figure 5-3. Map View from Bike Arlington Bicycle and Pedestrian Counters Website

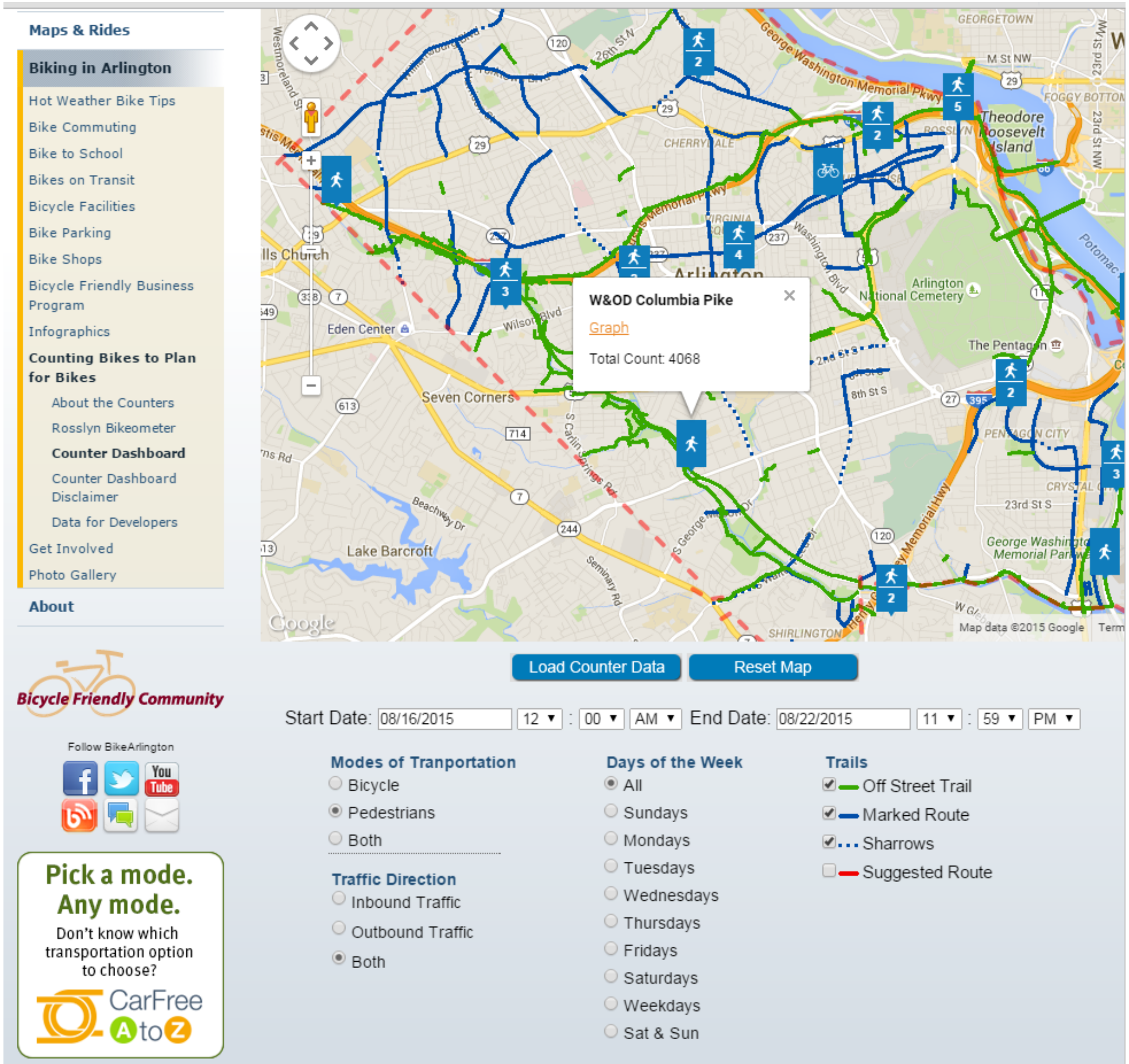
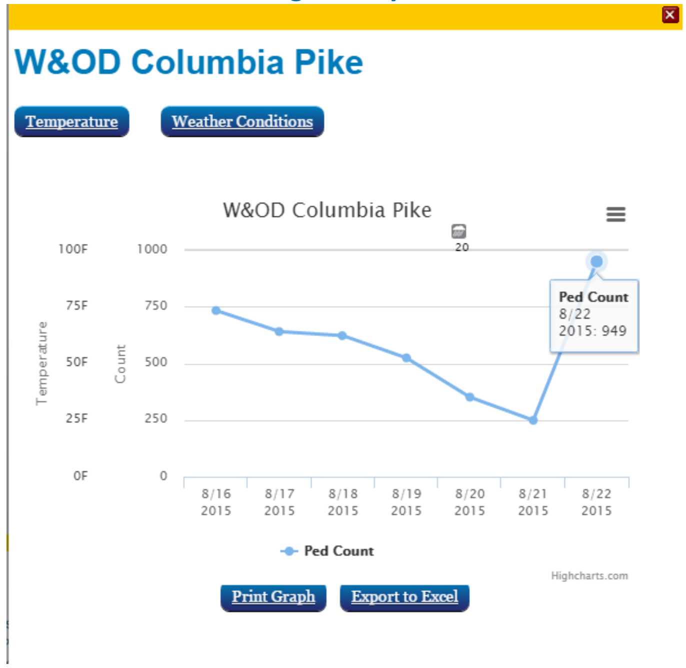


Figure 5-4. Data View from Bike Arlington Bicycle and Pedestrian Counters Website



Portland State University Bike-Ped Portal.[157] This site is currently password-protected (i.e., not public), but is intended to become public in the near future. It offers data storage for bicycle and pedestrian counts from multiple jurisdictions. The site is designed for automated count data but also includes manual counts. Pedestrian data currently available is primarily from manual counts, but the site includes data from both continuous and mobile automated counters. The site is under development, but the version currently available includes a list of count devices, count sites, and allows users to upload and download comma-delineated data files of each.

Southern California Association of Governments (SCAG) Bike Count Data Clearinghouse.[158] The SCAG Bike Count Data Clearinghouse is designed primarily for manual count data, but data from automated counters can be entered. The site offers Los Angeles area governments the ability to upload data. While the site is focused on bicycle counts, pedestrian counts are being collected and will be supported in future versions. The site offers the ability to both upload and download data as well as shows the maximum count for each location.

Travel Monitoring Analysis System (TMAS). While TMAS is not currently available to the public, it can be accessed by transportation professionals who would like to obtain access. While TMAS does not currently accept pedestrian count data, the next version of TMAS will include the ability to upload TMG-formatted both pedestrian and bicycle (nonmotorized) station and count data to the system. The system includes the ability to upload data, automated quality control (customized by site), reporting of data, deletion of data, and exporting of data as well as some analysis tools. Should your agency be interested in obtaining access, contact Steven Jessberger at 202-366-5052 or email at steven.jessberger@dot.gov.

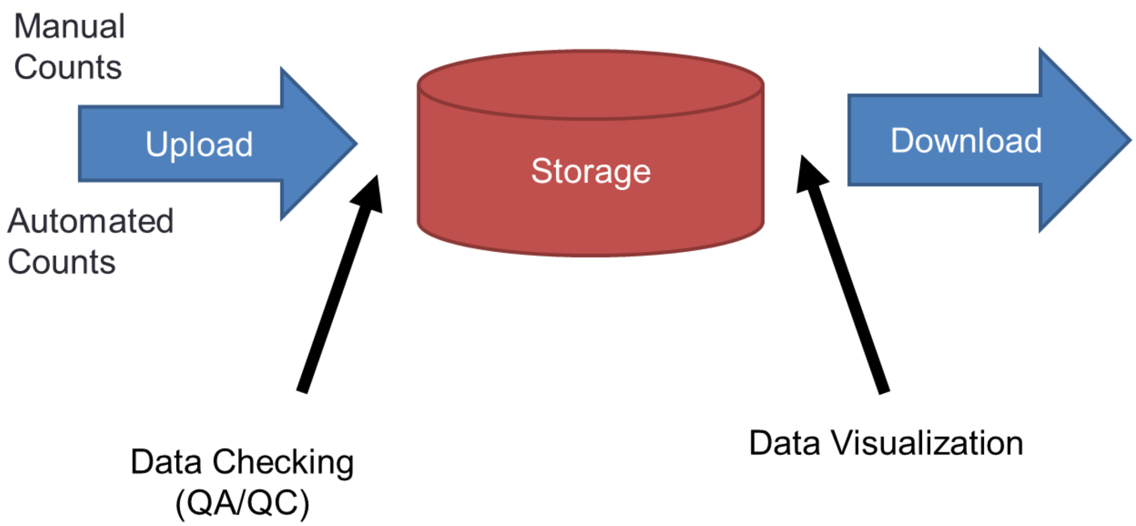
In addition to the above five government funded and operated sites, there are two counting equipment vendors that host privately operated archives for pedestrian data primarily for their vendor specific count data: Eco-Visio by Eco-Counter and DataNet by TRAFx. These are also described in Table 5-4.

There are also software quality control contractors who provide processing, QC and storage capability to agencies for their motorized and nonmotorized data. The three main contractors in the US are High Desert, MS2 and Transmetric.

DATA MANAGEMENT – SUMMARY OF FINDINGS

These basic elements of data management and storage are summarized in Figure 5-5.

Figure 5-5. Basic Elements of Data Management and Storage



Once an agency has created an online site to share data, there are three basic steps in making data available and accessible, and at each step there are opportunities to adopt best practices that maximize the ease and utility of sharing data.

- **Uploading data to the site**: Data must be entered in a standard format and checked for errors prior to or during the upload process. Most online databases present data from the agency maintaining the site, and do not allow third parties to upload data. Allowing upload can expedite the process of collecting data from different providers, but requires extra effort to standardize the format and coordinate quality checks across multiple organizations. Documenting the source of the data is part of the process.
- **Data storage**: Once data has been uploaded, the database can provide the capability of viewing the data online. Data should be secured and regularly backed up to ensure that data is available on a reliable basis. The most engaging sites include data visualization tools that provide maps or charts of the data. Data quality ratings can help users understand how the data can be applied and help data suppliers improve their data sets.
- **Downloading data from the site**: In order to make it easy for users to conduct their own analyses of the data, sites can provide data to users either in an interactive mapping format via an application program interface (API) or make data available for download in a frequently-used data file format, such as a comma-delineated file.

Table 5-4 summarizes the data collected by the sites reviewed, as well as the type of data visualization provided and any data sharing allowed. Another aspect of data sharing is documenting the source of the data and validating the data. Details of data validation are discussed in Section 5 Quality Assurance and Control.

Table 5-4. Examples of Online Nonmotorized Traffic Count Archives

Organization & Site	Data Types		Data Visualization		Data Sharing		Other
	Duration	Automated data	Map	Graph	Allows download	Allows upload	
DVRPC Pedestrian and Bicycle Counts	One week	✓	✓	✓	✓		Includes weather
BikeArlington Bicycle and Pedestrian Counters	Continuous	✓	✓	✓	✓		Includes weather
Portland State University Bike-Ped Portal **	Any	✓	✓	✓*	✓	✓	
SCAG Bike Count Data Clearinghouse	2 hour		✓		✓	✓	
TMAS**	5,10,15, 20, 30, 60,120 min.	✓		✓	✓*	✓*	Does not yet accept pedestrian data but is expected to in 2016.
Eco-Visio**	15, 60 min	✓	✓	✓	✓	✓	Includes weather
DataNet**	60 min	✓	✓	✓	✓	✓	

* This aspect of the site is currently under development.
** Currently password-protected and not accessible to the public.

With the exception of Bike-Ped Portal and TMAS, which have the flexibility to handle data from counts of different durations, each of the sites that we reviewed is set up to accommodate only data collected through the type of counts typically used by the administering agency. Most sites can accommodate automated data. It is common practice to provide maps or charts visualizing data, as well as to make data available for download. However, only some sites allow users to upload data.

There are relatively few publicly available (not password-protected) online sites that make pedestrian data available, and many of those that do exist are only set up to handle data from counts of a specific duration, and do not allow users to upload data. Password protected online sites allow data upload and more extensive analysis tools. Common best practices include:

- Making data available for download in a documented data format.
- Including a map showing count location, graphs of trends in pedestrian volumes, and links to weather data
- Making data available via an API.
- Including information on the data source and quality, if available.

DATA ANALYSIS

Overview

In order for count data to be useful, count data must be summarized in metrics that are useful to practitioners, from regional travel demand modelers to safety analysts to economic development specialists looking to assess pedestrian vitality in a business district. Depending on the particular reason for the pedestrian counts (event management, safety, project development, etc.), different metrics may be needed.

Though the metrics used by different practitioners vary widely, in all cases analysts can benefit from understanding how volumes vary over time and across space. For example, in order to report annual pedestrian volumes, which is a commonly used metric, based on counts conducted at a specific time of day and year, it is necessary to understand how volumes vary throughout the day and as the seasons change. As with motorized traffic counts, pedestrian counts are typically annualized using adjustment factors, but because of the relative lack of data on nonmotorized travel fewer resources have identified adjustment factors. This subsection reviews research on temporal and spatial adjustment factors and identifies common metrics used to summarize data.

Review of Resources

Temporal Variation

Few temporal adjustment factors have been developed for pedestrians. Alta Planning and Design has developed factors that are publicly available through the NBPDP website.[159] For bicycling, researchers have discovered that because bicycle patterns are so weather dependent, day-of-year factors can improve estimates of annual daily traffic from short-duration counts.[160] Further research is needed to determine whether the same is true for pedestrians.

Schneider, Henry et al. and Hankey, Lindsey et al. studied pedestrian traffic patterns and found that common patterns include one peak during the middle of the day, and some locations with peaks in the evening or even at night when bars let out. They have also found that pedestrian traffic is less impacted by weather and season than bicycle traffic, but more than motor vehicle traffic.[161] However, more research is needed to identify how pedestrian volumes vary over the course of the day.

Spatial Variation

Pedestrian travel patterns can be highly variable. Conversation with pedestrian counting expert Robert Schneider, professor at the University of Wisconsin Milwaukee suggests that pedestrian patterns may vary from sidewalk to adjacent sidewalk and between crosswalks and adjacent sidewalks.[162] Pedestrian travel varies from street to street, and city to city. For this reason, understanding spatial variation across a network is important.

On the small scale, counting the total volume of pedestrians passing through an intersection is common. However, for safety studies, volumes per crosswalk by direction of crossing are counted. It is common practice but inaccurate to translate crosswalk counts into total volume per intersection counts. The sum of the crosswalk counts for a given intersection is not the same as the total volume of pedestrians traveling through that same intersection, because some pedestrians will cross multiple crosswalks in the same intersection, while those who turn right will pass through an intersection without crossing any crosswalks.

Another issue is that unless counts are conducted on every sidewalk, crosswalk, alley way, and path, analysts must extrapolate data from a limited number of locations to estimate volume across an entire network, which may be useful for safety studies, travel demand model validation, or economic development analysis. Research on bicycle travel from Montreal suggests that count data combined with GPS data can fill that gap.[163] An interview with study author Professor Luis Miranda-Moreno at McGill University indicates that other data sources, such as Wi-Fi detection, may also be useful.[164] This combination of data types may be especially useful for understanding pedestrian traffic throughout a network.

One metric for measuring this pedestrian volume on a network is Pedestrian Miles Traveled (PMT). This is simply the length of each facility multiplied by the pedestrian traffic volume on that facility, summed over the network or study area. Research from Washington State investigated this on the state level.[165]

Temporal and Spatial Metrics - Findings

Common temporal summary metrics include:

- Total pedestrians per hour, day, and year
- Average pedestrians per hour of the day, day of the week, month of the year, and per year.
- Peak hour pedestrians.

For pedestrians, peak hour pedestrians is not well defined. Commonly, the maximum hour recorded is reported as the peak hour, but further research is needed to determine if the 30th highest peak hour for the year (similar to motor vehicle peak hour) would be more appropriate or if a different metric for peak hour would be more appropriate for pedestrians.

The NBPDP provides temporal adjustment factors that can be used to estimate annual volumes based on daily volumes. However, little research is available to estimate daily volumes based on limited-duration counts.

Common spatial summary metrics include:

- Total pedestrians, for street segments
- Total pedestrian volume, for transportation demand studies of intersections.
- Pedestrians per crosswalk, for safety studies of intersections.
- Pedestrian Miles Traveled (PMT) for a network or an area.

The existence of two common metrics for intersection studies can create confusion; more guidance is needed to help practitioners distinguish and translate between the two.

VENDOR OUTPUT

Overview

In order to understand data management, it is important to understand the types of data formats currently available. This section focuses on automated count data, but also includes some standard formats for manual count data collection as this is a common source of pedestrian count data.

The purpose of this section is not to provide an exhaustive inventory of all data formats, but to provide examples of various data types that are currently available.

Review of Vendor Output Formats

To provide a range of examples of pedestrian count data formats, we will discuss the manual count formats from the National Bicycle and Pedestrian Documentation Project (NBPDP) and from the standard format used to track intersection turning movements, automated counts from two prominent vendors: Eco-Counter and TRAFx. All of the example data from automated counters shown are from passive infrared counters, meaning that they count all warm bodies as a single value. The devices do not distinguish between bicycles and pedestrians.

Manual Counts: National Bicycle and Pedestrian Documentation Project

The NBPDP was the first national-level effort to create a standard format for bicycle and pedestrian counts. It was initiated as a joint effort between the Institute of Transportation Engineers (ITE) and Alta Planning and Design in 2004 in response to the lack of widely available bicycle and pedestrian data.[166] The NBPDP website provides standard forms, instructions, and other information for agencies interested in counting nonmotorized traffic. The NBPDP has helped and encouraged many jurisdictions around the nation to start bicycle and pedestrian counting programs. It is designed for manual count data; automated pedestrian data collection has evolved significantly since the NBPDP was created.

Table 5-5 and Table 5-6 show the NBPDP data format, which includes metadata and two time periods of count data. Additional count records would be added as rows below “Count #2 Data” and additional count locations would be added as additional columns to the right of the column labeled “Loc. #3.” Counts are collected as bicycle, pedestrian, and other, in which “other” includes equestrians, skate boarders, and roller bladders.

Table 5-5. NBPDP Background Datasheet (Metadata)

Agency/Organization:	Enter here		
ID #:	Enter here		
Date sheet completed:	Enter here		
Contact Information:	Enter here		
Lead Person Name	Enter here		
Address	Enter here		
E-mail	Enter here		
Phone	Enter here		Region
General Area Background:	Local Community	County	
Name of jurisdiction(s):	Enter here	Enter here	
If County or Region, # of local agencies:			Enter here
Source of demographic data:	Enter here		
Year of data:	Enter here	Enter here	Enter here
Population:	Enter here	Enter here	Enter here
Density (people per square mile):	Enter here	Enter here	Enter here
Bicycle Mode Share: US Journey to Work		Enter here	Enter here
Pedestrian Mode Share: US Journey to Work		Enter here	Enter here
Median Age:		Enter here	Enter here
Median Income:	Enter here	Enter here	Enter here
Number of annual visitors to area:			Enter here

Table 5-6. NBPDP Background Datasheet (Count Location Description)

Agency/Organization:	Enter here		
Count Location Description:	Loc. #1	Loc. #2	Loc. #3
Type of facility:	Enter here	Enter here	Enter here
Type of setting:	Enter here	Enter here	Enter here
Scenic Quality:	Enter here	Enter here	Enter here
Surrounding land uses:	Enter here	Enter here	Enter here
Schools, parks, visitor destinations within 1 mile:	Enter here	Enter here	Enter here
Quality of connecting facilities:	Enter here	Enter here	Enter here
Length of facility:	Enter here	Enter here	Enter here
Access:	Enter here	Enter here	Enter here
Quality of overall network:	Enter here	Enter here	Enter here
Traffic volumes (ADT):	Enter here	Enter here	Enter here
Traffic speeds (posted):	Enter here	Enter here	Enter here
Crossings and intersections:	Enter here	Enter here	Enter here
Crossings and intersection traffic:	Enter here	Enter here	Enter here
Crossings and intersection protection:	Enter here	Enter here	Enter here
Topography:	Enter here	Enter here	Enter here
Count #1 Data:			
Date Collected:	Enter here	Enter here	Enter here
Time Period:	Enter here	Enter here	Enter here
Weather:	Enter here	Enter here	Enter here
Bicycles:	Enter here	Enter here	Enter here
Pedestrians:	Enter here	Enter here	Enter here
Other:	Enter here	Enter here	Enter here
Count #2 Data:			
Date Collected:	Enter here	Enter here	Enter here
Time Period:	Enter here	Enter here	Enter here
Weather:	Enter here	Enter here	Enter here
Bicycles:	Enter here	Enter here	Enter here
Pedestrians:	Enter here	Enter here	Enter here
Other:	Enter here	Enter here	Enter here

Recently, apps have been developed for use with smart phones and other mobile devices which aid in collecting manual pedestrian count data, but often volunteers and others still enter data on paper and enter it into spreadsheets later.

Manual Counts: Intersection Turning Movements

Intersection turning movement counts are a common data type. While the exact format of the data varies by vendor, by intersection, and by jurisdiction, the basic concept is the same. Data can be collected directly in the field or entered from videos. Counts can be collected by volunteers, staff or traffic monitoring firms, and data are often entered in electronic count boards and output in spreadsheet format. Figure 5-6 shows an example of the spreadsheet format.

Figure 5-6. Example Manual Turning Movement Count Using JAMAR Count Board[167]

File Name:	C:\Program Files\JAMAR\PetraPro\Data Files\HNTB\CCD TIMING\1\14TH&ARAPAHOEPM.p
Start Date:	11/6/2007
Start Time:	4:00:00 PM
Site Code:	00000000
Comment 1:	Default Comments
Comment 2:	Change These in The Preferences Window
Comment 3:	Select File/Preference in the Main Scree
Comment 4:	Then Click the Comments Tab

	ARAPAHOE Southbound				14TH ST Westbound				ARAPAHOE Northbound				14TH ST Eastbound			
Start	Left	Thru	Right	Peds	Left	Thru	Right	Peds	Left	Thru	Right	Peds	Left	Thru	Right	Peds
16:00	41	56	0	16	0	0	0	33	0	0	20	4	0	95	2	4
16:15	47	60	0	0	0	0	0	28	0	0	21	3	0	91	4	1
16:30	42	78	0	4	0	0	0	19	0	0	19	4	0	82	5	1
16:45	51	79	0	11	0	0	0	33	0	0	18	11	0	80	10	3
17:00	54	116	0	13	0	0	0	51	0	0	11	30	0	103	13	5
17:15	33	72	0	11	0	0	0	37	0	0	29	31	0	123	18	0
17:30	45	81	0	18	0	0	0	46	0	0	40	26	0	96	16	14
17:45	41	82	0	31	0	0	0	45	0	0	22	26	0	117	16	0

As discussed above, though apps are available to support manual pedestrian counts, most agencies still use paper and clipboard to do pedestrian intersection counts. However, in some cases, such as Washington State's Bicycle and Pedestrian Documentation Program, volunteers enter count data from their paper forms used in the field directly into an online database. This avoids additional staff time to aggregate this data.

Automated Counts: Eco-Counter

Eco-Counter sells passive infrared counters for counting pedestrians on off-street trails and sidewalks. Figure 5-7 shows an example of the standard data format for Eco-Counter devices. The first and second columns list the start date and time of the count period. The third column lists the total volume and the fourth and fifth column list the pedestrians counted in the each direction.

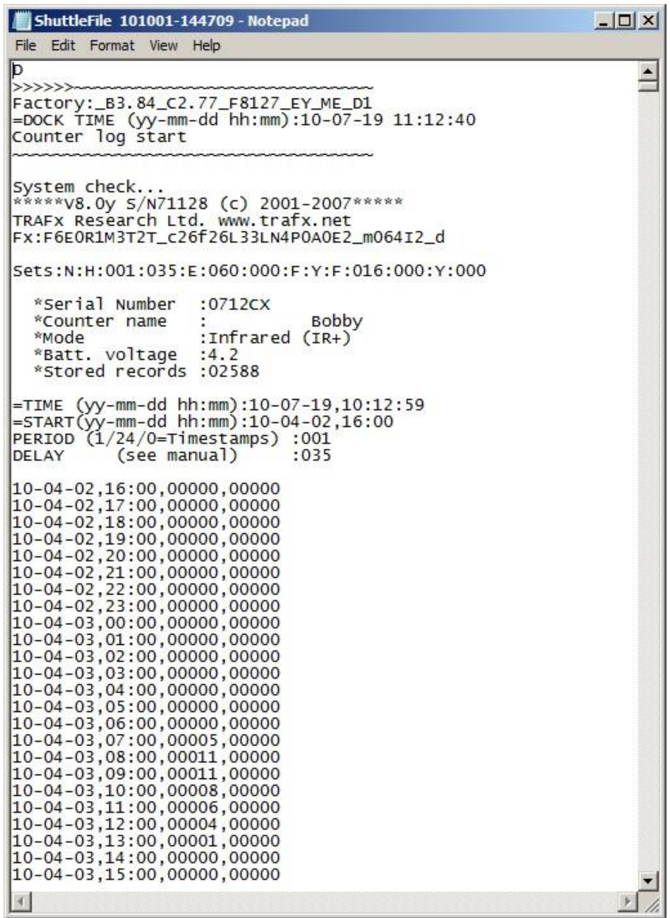
Figure 5-7. Eco-Counter Pedestrian Count Output

		TREC	Pyrobox_H-9_IN	Pyrobox_H-9_OUT
17/06/2014	14:00	0	0	0
17/06/2014	14:15	0	0	0
17/06/2014	14:30	0	0	0
17/06/2014	14:45	2	1	1
17/06/2014	15:00	0	0	0
17/06/2014	15:15	67	44	23
17/06/2014	15:30	77	46	31
17/06/2014	15:45	5	3	2
17/06/2014	16:00	4	4	0
17/06/2014	16:15	2	1	1
17/06/2014	16:30	1	1	0
17/06/2014	16:45	3	1	2
17/06/2014	17:00	0	0	0
17/06/2014	17:15	2	1	1
17/06/2014	17:30	4	1	3
17/06/2014	17:45	0	0	0
17/06/2014	18:00	0	0	0

Automated Counts: TRAFx

TRAFx is another vendor of pedestrian counting equipment; its passive infrared counters are commonly used to count pedestrians in parks across North America. Figure 5-8 shows an example of TRAFx raw pedestrian count data, which is supplied by the vendor in CSV format. The first two columns indicate the start date (yy-mm-dd) and time, and the third indicates the total pedestrian traffic volume. This example comes from a non-directional counter.

Figure 5-8. TRAFx Raw Data Format




```
p
>>>>>>~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Factory:_B3.84_C2.77_F8127_EY_ME_D1
=DOCK TIME (yy-mm-dd hh:mm):10-07-19 11:12:40
Counter log start
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

System check...
*****V8.0y S/N71128 (c) 2001-2007*****
TRAFx Research Ltd. www.trafx.net
FX:F6E0R1M3T2T_c26f26L33LN4P0A0E2_m064I2_d

Sets:N:H:001:035:E:060:000:F:Y:F:016:000:Y:000

  *Serial Number  :0712CX
  *Counter name   :           Bobby
  *Mode           :Infrared (IR+)
  *Batt. voltage  :4.2
  *Stored records :02588

=TIME (yy-mm-dd hh:mm):10-07-19,10:12:59
=START(yy-mm-dd hh:mm):10-04-02,16:00
PERIOD (1/24/0=Timestamps) :001
DELAY     (see manual)     :035

10-04-02,16:00,00000,00000
10-04-02,17:00,00000,00000
10-04-02,18:00,00000,00000
10-04-02,19:00,00000,00000
10-04-02,20:00,00000,00000
10-04-02,21:00,00000,00000
10-04-02,22:00,00000,00000
10-04-02,23:00,00000,00000
10-04-03,00:00,00000,00000
10-04-03,01:00,00000,00000
10-04-03,02:00,00000,00000
10-04-03,03:00,00000,00000
10-04-03,04:00,00000,00000
10-04-03,05:00,00000,00000
10-04-03,06:00,00000,00000
10-04-03,07:00,00005,00000
10-04-03,08:00,00011,00000
10-04-03,09:00,00011,00000
10-04-03,10:00,00008,00000
10-04-03,11:00,00006,00000
10-04-03,12:00,00004,00000
10-04-03,13:00,00001,00000
10-04-03,14:00,00000,00000
10-04-03,15:00,00000,00000
```

Count Formats - Findings

The two automated count formats reviewed are similar, with fields for date, time, and count data. Manual count formats include these data, but vary more widely, distinguishing between modes (pedestrian vs. bicycle) and, in the case of intersection counts, movements in count data. Manual formats may include more varied metadata on weather and the location in which the count was performed.

TMG STATION RECORD DATA AND VOLUME DATA

Overview

This subsection reviews the existing TMG station record requirements and volume data. These formats allow count data to be added to the Travel Monitoring Analysis System (TMAS), the U.S. Department of Transportation's database for travel data. The TMG Chapter 7.9 and 7.10 specifies two separate formats, one for station records and another for count records.[168]

Ten of the fields are the same in both formats. Each record corresponds to one line in a data input file. The TMG format is in a fixed-width text format in which each character in the record is considered to be in a separate "column." Since fields are not separated by commas or other delimiters, it is critical that each character be in the correct "column." If an extra space, comma, or any other character is added to the record, the characters following it will be incorrectly read by TMAS. Fields in the TMG are indicated with a "C" for critical if they are required or an "O" for optional. Fields that are required only in some situations are designated with an "O/C."

Station Record[169]

Each field in the station record is described below, and an example of station record data is provided at the end of this subsection in Figure 5-10. Note that there are three fields that work together to identify the location of the count station: direction of route, location of count relative to roadway orientation, and movement direction. In some cases, the fields "crosswalk, sidewalk, exclusive facility or total intersection count" and "intersection" also provide information the type of count. We identify each field with its name, information in whether it is required (C, O, or C/O), and column number, **(Field Name, C/O, Column Number)** which is the number of characters from the beginning of the row, such that Column 1 refers to the first character in the row and Column 60, the 60th character in the row.

Nonmotorized station/location record identifier (C, 1): The first character in a pedestrian station record is the letter "L" which is used to alert the system that the record is a nonmotorized traffic station record.

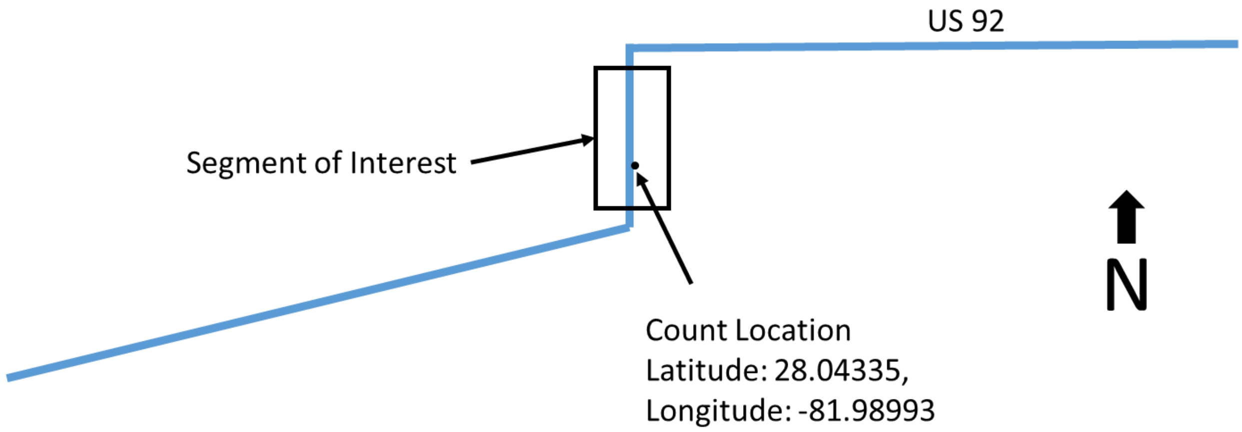
State and County FIPS Codes (C, 2-6): The next two fields are the Federal Information Processing Standards (FIPS) codes for the state and county. The state code can be found in Table 7-32 on Page 7-72 of the TMG, but the three digit county codes must be looked up from the Federal Information Standards Publication 6.[170] Figure 5-10 below is for Multnomah County (051) in Oregon (41).

Station ID (C, 7-12): The next six columns of the station record are reserved for the Station ID. This is a code unique to the count station. It may be determined by the jurisdiction collecting the data but should be coordinated with the state in order to prevent repetition. The ID is right justified, such that if the Station ID is the number 22, the values in the six columns would be 000022, as shown in Figure 5-10.

Classification of road (C, 13): The next column is the one digit code for the functional classification for the roadway or path as listed in Table 7-33 of the TMG on page 7-73. This will be expanded to two digits in future versions of the TMG, with the second digit being either U for Urban or R for Rural. The traditional roadway classifications are expanded in this table to include two new nonmotorized traffic specific classes: "Trail or Shared Use Path" and "General Activity Count." If a trail or shared use path is adjacent to, parallel to, and associated with a roadway, the functional classification of the roadway should be used, not the Trail or Shared Use Path code. Similarly, if the pedestrians counted are on a sidewalk or crosswalk, the functional classification of the associated roadway should be used. A general activity count refers to a count of pedestrians in an open area or plaza, like the National Mall in Washington, D.C. In the example below the pedestrian count is from a shared use path immediately adjacent to a Minor Arterial, so the code is 4.As is illustrated in Figure 5-10 below.

Direction of Route[171] (C, 14): This field contains an integer that refers to the direction of the overall route (often the motor vehicle route) associated with the pedestrian traffic. Table 7-34 in the TMG lists the values of the direction of route.[172] Direction of route does not always correspond with the actual direction of pedestrian or flow at the location where the count is collected, but instead refers to the overall direction of flow along a numbered route. For example, an east-west route may have north-south roadway segment, where a user may identify the direction of route as north when according to the TMG it should be east, as shown in Figure 5-9.

Figure 5-9. Direction of Route Does Not Match Direction of Pedestrian Travel



Note: The latitude and longitude in the above diagram is not TMG formatted.

Location of count relative to roadway orientation (C, 15): This field contains a numeric value indicating where the pedestrian count was collected relative to a roadway based on the “direction of route” field. If the count is taken on the side of the road closest to the motor vehicles traveling in the “direction of route,” the code is 1. If the pedestrian count is taken on the opposite side of the road from the vehicles traveling in the “direction of route,” the code is 2. If pedestrians on both sides of the roadway are being counted at the same time, the code is 3. These codes are also used for facilities that are not along a roadway, since the user will have identified a direction of route in the previous field. If the pedestrians counted are crossing a roadway, the code is 4, indicating pedestrian travel is perpendicular to the roadway. In the example coding, the code 1 indicates that pedestrians counted are traveling on a sidewalk on the east side of the north-south section of the east-west route shown in Figure 5-10.

Direction of travel (C, 16): This field indicates the direction of pedestrian travel relative to the direction of route. If pedestrians counted are moving in the same direction as the direction of route the code is 1. If pedestrians counted are moving in the opposite direction, the code is 2. If pedestrians are moving in both directions or for general activity counts, the code is 3. If pedestrians are moving both directions in a crosswalk perpendicular to the direction of route, the code is 4. This coding means that pedestrians in a crosswalk cannot be separated by direction of pedestrian travel. In the example, code 3 indicates that pedestrians counted are traveling in both directions.

Crosswalk, sidewalk, exclusive facility, or total intersection count (C, 17): This field identifies the type of facilities on which pedestrians are traveling using the following codes:

- 1: roadway shared with motor vehicles
- 2: crosswalk.
- 3: sidewalk
- 4: shared-use path that operates like a wide sidewalk associated with a roadway (this will change to Code 8 in the updated TMG).
- 5: pedestrian-only or shared use path overpass over a roadway
- 6: pedestrian-only or shared use path underpass under a roadway.

In the revised version of the TMG, the following codes will be added:

- A: general area count

- 0: trail or shared-use path in its own right of way or sufficiently separated from a roadway that it operates as a separate facility

If pedestrians counted are crossing a street within a block where there is no crosswalk, the updated TMG will direct users to code the facility as 1. In the example of the sidewalk shown below in Figure 5-10, this field is coded 3.

Intersection (O, 18): This optional field indicates if the count is collected at a roundabout (code “1”) or a non-roundabout intersection (code “2”). If the pedestrians counted are not at an intersection, the field is blank. Blanks are entered as underscores (“_”) in the TMG format. In the sidewalk example shown below in Figure 5-10, this would be left blank.

Type of count (C, 19): This field indicates the mode of travel. Code “1” indicates that only pedestrians are counted. If pedestrians and bicycles are both being counted, this field is coded as “4”. If all nonmotorized traffic is counted including bicyclists, equestrians, skate boarders etc., this field is coded as “5”. If all motorized and nonmotorized traffic using the facility is included in the count, this field is coded as “6”. Code 6 could include snowmobiles along with snowshoers (pedestrians) and skiers, for example. In the sidewalk example shown below in Figure 5-10, the code is 1 for a pedestrian-only facility.

Method of counting (C, 20-21): This field indicates if the count was collected by a human observer (code 1), by a portable automated traffic counter (code 2), or by a permanent continuous counter (code 3). Even though this is a two-column field, only one column is needed, so the first character is zero. For example, if the count on the sidewalk was collected by a portable passive infrared counter, the field would be coded as “02.”

Type of sensor (O, 22-23): This field indicates the type of sensor used. If more than one sensor type is used, this field is coded as “9”. If the sensor is a human being in the field counting pedestrians with or without electronic count boards, it is coded as H. If the pedestrians are videotaped and counted manually in the office later by a human, it is coded as “1”. If the video is processed by automated or semi-automated image processor software which converts images to counts, it is coded as V. The rest of the code options designate various technologies, including passive infrared (code I), active infrared (code “2”), sonic/acoustic (code “S”), and other pressure mat (code “3”), as shown on page 7-76 of the TMG. Even though this is a two-column field, only one column is needed, so the first character is an underscore “_”. For example, if the count was collected by a portable passive infrared counter, the field would be coded as “_I”.

Year (C, 24-27): This field shows the year in which the count was collected. In Figure 5-10 below, the data were collected in 2014.

Factor Groups (O, 28-32): The next five fields are optional factor group fields which fill one column each. The values of these groups are left to the data submitters so that they are able to list factor groups for each station. The value in the field is not the factor itself, but a code for the factor group in which the station should be included, e.g., time-of-day factors, day-of-week factors, monthly factors, bias compensation factors, and weather factors. These can all be left blank if no factor groups are being used, as shown in Figure 5-10 below.

Primary Count Purpose (O, 33): This is a single column field that indicates the purpose of the count: “O” for operation and management of facilities, “P” for planning or statistical reporting,[173] “R” for research, “S” for Safe Routes to School, “L” for facility design, and “E” for enforcement. In our example in Figure 5-10, the purpose is left blank as an underscore “_”.

Posted Speed Limit (O, 34-35): This field indicates the speed limit on the roadway or path in miles per hour. In Figure 5-10, the speed limit is "45" for 45 miles per hour.

Year Station Established (O, 36-39): This field contains the year the station began recording. In Figure 5-10 this is 2010.

Year Station Discontinued (O, 40-43): This field is the year in which the station was discontinued. Our fictitious example station was not discontinued, so the field is left blank, as illustrated in Figure 5-10.

National Highway System (O, 44): This field shows and "N" for no if the count is collected on or associated with a roadway not in the National Highway System and "Y" for yes if it is in the National Highway System. In Figure 5-10, the roadway is part of US route 92, so it is part of the national highway system and thus coded as "Y".

Latitude (C, 45-52): This field assumes that the latitude is in the northern hemisphere such that the decimal place would appear between the second and third columns. In the example illustrated in Figure 5-10, the latitude is 28.04335, so this is coded as "28043350" (the additional zero is added to the end to ensure that the field is the required eight characters).

Longitude (C, 53-61): This assumes that the longitude is in the western hemisphere such that the negative sign is dropped and the decimal place would appear between the third and fourth columns. In Figure 5-10, the longitude is -81.98993 which would be coded as "081989930" (the additional zero is added to the end to ensure that the field is the required nine characters).

Posted Route Signing (O, 62-63): This field refers to the route signing codes listed in Table 7-35 in the TMG, which indicate the type of route from the HPMS Field Manual.[174] In Figure 5-10 the route is posted as US 92, and the code for a US route is 03.

Posted Signed Route Number (O, 64-71): This field refers to the route number of the posted route signing. If the roadway associated with the count is not on a signed route, as for a city street, the field should be filled with zeros. For trails that are not part of a designated U.S. Bike Route, the field should be filled with zeros. This field is right-justified, so in Figure 5-10, Route 92 is entered as "00000092."

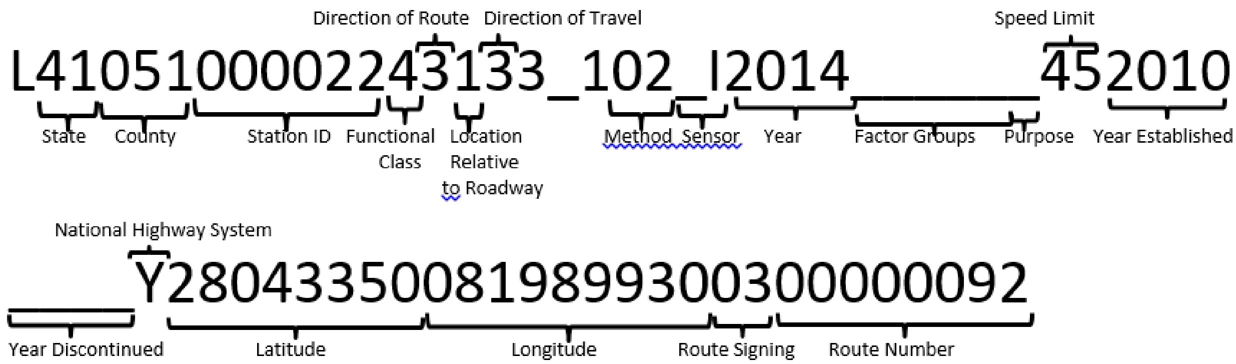
Linear Referencing System Identification (O, 72-131): This optional field can be used to join the count data to geocoded data. It can be composed of letters or numbers, but not blanks. This field is right justified, so unused columns are entered as leading zero values. This field is not shown in Figure 5-10 because it is both optional and long.

Linear Referencing System Location Point (O, 132-139): This field is the distance along the route (in miles, to the nearest thousandth of a mile) to the count station from the defined start of the roadway. As with latitude, the decimal is not used, but implied in the middle of the field, between the fourth and fifth characters. This field is not shown in the example in Figure 5-10 because it is both optional and long.

Station Location (O, 140-189): This is a 50-character text field describing the location of the site. The text should be left justified. If the station is on a trail or city street, this field will include the trail or street and city name, potentially abbreviated to meet the character limit. This field is not shown in the example in Figure 5-10 because it is both optional and long.

Other Notes (O, 190-239): This is a 50-character text field for other notes. This field is not shown in the example in Figure 5-10 use it is both optional and long.

Figure 5-10. Example Station Record in TMG Format



Note: The record example above is shown on two separate lines, but in reality, it would all be on one row of text. Additional optional information can be added at the end of this record, such as linear referencing system information, station location and other notes.

Volume Record

This subsection describes each field in the volume record except for the ten fields that are identical to those used in the station record, which are described above: State FIPS Code; County FIPS Code; Station ID; Route Direction; Location of count relative to roadway orientation; Direction of travel; Crosswalk, sidewalk, or exclusive facility; Intersection; Type of count (pedestrian); and Type of sensor.

Nonmotorized Count Record Identifier (C, 1). The first character in a pedestrian station record is the letter "N," which is used to alert the system that the record is a nonmotorized traffic station record.

State and County FIPS Code and Station ID: The next three fields of the Count Record contain the State and County FIPS Code and the Station ID, and are identical to these fields in the Station Record.

Latitude and Longitude Fields: Columns 13 through 20 contain the latitude and longitude and are the same as Columns 45-61 in the Station Record.

Direction of Route Field through Type of Count Fields: Columns 30 through 35 in the Count Record are identical to Columns 14 through 19 in the Station Record.

Type of Sensor: Columns 36 through 37 in the Count Record are identical to Columns 22 through 23 in the Station Record.

Precipitation (O, 38): This field indicates if measurable precipitation was observed during the count period. If precipitation has been observed, it is coded as one. If not, it is coded as two. If unknown, the field is filled with a blank (designated with an underscore).

High Temperature (O, 39-41): This integer field is the high temperature for the day, or for the count period if the count is less than a day in duration. Temperatures are entered in whole numbers in degrees Fahrenheit and are right-justified, such that zeros are entered in the first and second column in the case of two- or one-digit temperatures. For example, a day with a high of 62.3 degrees Fahrenheit would be coded "062".

Low Temperature (O, 42-44): This integer field is the low temperature for the day or for the time period of the count in degrees Fahrenheit. The format for this field is the same as for the High Temperature field described above.

Year of Count (C, 45-48): The year in which the count was collected, same as Columns 24-27 in the Station Record.

Month of Count (C, 49-50): The month in which the count was collected is entered as a two digit integer where January is indicated as 01 and December as 12.

Day of Count (C, 51-52): The day of the month on which the count was collected is entered as a two digit integer where the eight day of the month is entered as 08.

Count Start Time for This Record (C, 53-56): This field contains the start time for the count period, expressed in military time with colons removed. For example, 9:00 AM would be entered as 0900 and 1:00 PM would be entered as 1300. Round numbers are used, such that hour counts should not start at 9:33 AM, but at 9:00 AM or 10:00 AM. If the count is a full day count, it is assumed to begin at midnight, with a value of 0000.

Count Interval Being Reported (C, 57-59): This field indicates the number of minutes in each count interval. Options are 5, 10, 15, 20, 30, 60, or 120-minute intervals. For example, counts in one hour intervals would be coded as 060. Data from different days should be submitted in separate records.

Count Interval 1 (C, 60-64): This integer value indicates the volume of pedestrian (and other modes if the counts are not separated by mode) traffic recorded during the count interval. If the count is 45, the record would read "___45," with three underscores preceding the two-digit value. If no counts were recorded the record would read "____0" with four underscores preceding the zero in Column 64.

The remaining columns are all optional, up to a maximum of 2500 columns. All counts in a record must be taken during the same day. Each additional interval count is an additional five characters and follows the same coding rules described for Count Interval 1.

DATA MANAGEMENT – SUMMARY OF FINDINGS

The state of the practice in pedestrian data collection is evolving rapidly. However there are still many unanswered questions about how to best implement pedestrian count programs due to the nation's lack of experience with such programs. The following subsections summarize findings related to the four main aspects of data management covered in this section.

Quality Assurance and Control

Automated data collection is necessary to inform comprehensive pedestrian plans and analyses. Many resources identify quality assurance procedures for automated motor vehicle count data that can also be applied to pedestrian data, but further work is needed to develop best practices that account for the unique nature of pedestrian data, including:

- Developing guidelines for data completeness: Less complete pedestrian count data, such as two-hour counts, can still be useful for some purposes such as early in the planning process for a new facility, while high data completeness is needed for other purposes such as facility-specific safety analysis.
- Identifying specific procedures to verify and calibrate automated equipment using manual ground truth counts on installation, and annually thereafter for continuous count stations.
- Developing automated validation criteria for pedestrian counts, such as comparison with historical counts, multiple days with consecutive zeros, missing data, checks for outliers, and more than three repeating values and that all data be checked for proper format and missing

data and inspected manually by a trained professional. Current state of the practice is not well established and can result in flagging too much of the data as errors due to the highly variable nature of pedestrian counts.

- Developing bias compensation factors to account for systematic under- or over-counting due to occlusion and other equipment issues.

Standard Metadata

The TMG Chapter 7 provides a standard list of metadata. These are documented in detail in the station record description in TMG Section 7.9, as well as in the count record in TMG Section 7.10. Other data archives also give standard metadata. Below is a list of documented data fields (relevant TMG field names given in parenthesis).

- Station location, a text field describing the count location, include roadway name (Station Location)
- Station number, in format used by collecting agency (Station ID)
- Pedestrian facility type (Crosswalk, Sidewalk, or Exclusive Facility)
- Latitude and longitude (Latitude, Longitude)
- Direction of pedestrian travel (Direction of travel)
- Mode of travel (Type of count (bicycle/pedestrian/both))
- Weather (Precipitation, High temperature, Low Temperature)
- Start date and time (Year of Count, Month of Count, Day of Count, Count Start Time for This Record)
- Count interval (Count Interval Being Reported)

Accessibility and Distribution

Making data available online allows a variety of users to access it, but there are a limited number of online sources of bicycle and pedestrian data. Common best practices from current sources include:

- Making map data available using an application program interface (API).
- Making data available for download in a frequently used data formats, such as an Excel spreadsheet.
- Including a map showing count location, graphs of trends in pedestrian volumes, and links to weather data
- Including information on the data completeness and quality, if available.

A national online clearinghouse for pedestrian count data would help to standardize data collection efforts and make it easy for all users to access and analyze pedestrian data. FHWA's Travel Monitoring Analysis System (TMAS) can serve as a permanent data archive for pedestrian count data. The benefits of TMAS include cross-jurisdiction data sharing, analysis tools, and inclusion in a national dataset which can improve a jurisdiction's chances of funding for future projects, such as TIGER grants

Data Analysis

To standardize pedestrian count data in a way that simplifies data collection and maximizes comparability with motor vehicle traffic monitoring practice, the following standard summary metrics are suggested.

- Annual average daily pedestrians (AADP) or average daily pedestrians (ADP) if continuous counters are not available.
- Weekend and weekday AADP.
- Average pedestrians per hour of the day and day of the week.
- Monthly average daily pedestrians (MADP).
- Year over year change in pedestrian volume.
- Maximum hourly count for the year and location (at short-duration count sites) Usually maximum is listed since pedestrian counts are sparse, but as additional pedestrian data become available, the 30th highest peak hour for a given year at a given location (for continuous count sites), similar to motor-vehicle data, might be a metric of greater interest.

In order for these metrics to become standard practice, more research and guidance are needed to create adjustment factors that will help practitioners create summary metrics based on counts from different locations, dates, and times.

6. PEDESTRIAN COUNTING TECHNIQUES AND PROCEDURES - SUMMARY OF FINDINGS

This section provides conclusions and recommendations based on findings from the research. Each topic area is presented in the order that it appeared in the report.

CURRENT PRACTICE

Counting pedestrians is an important but challenging task: pedestrian activity is localized and heavily influenced by land use; pedestrian movements are not constrained to a given path; there are few automated technologies that capture pedestrians well; and some of the emerging technologies have not been widely tested. Review of the academic literature, coupled with feedback received during the webinar and interviews with experts, reveals that most agencies that collect nonmotorized count data are further along with bicycle data collection and monitoring than pedestrian data collection.

Of the 17 agencies with pedestrian count programs that we identified through our interviews and webinar, most (70 percent) indicated that infrared equipment is used for counting pedestrians. All but two agencies reported collecting short-duration counts, most of which (60 percent) were collected manually. A minority of responding agencies (35 percent) reported collecting continuous pedestrian counts. Only 30 percent of the respondents mentioned counting at intersections, while a majority (60 percent) indicated that they count on trails and paths. Sidewalks and mid-block crossings were also mentioned as count locations by multiple agencies. Only a third of respondents mentioned having both short-duration and continuous pedestrian count programs.

Agencies engaged during this research indicated more detailed guidance on best practices would be useful. Following is a list of recommended best practices that emerged from the research described in this section.

- Develop a strategic plan for counting pedestrians that includes both continuous and short-duration counts.
- Develop site selection criteria that will both ensure that valid data is collected from representative locations and capture high volume locations and other locations of particular interest.
- Count at both high-volume and low-volume locations.
- Count at pedestrian facilities other than sidewalks and intersections (e.g., overpasses, underpasses, stairs, elevators, and escalators).
- Consider the purpose, location, and duration of counts, as well as available resources, when selecting equipment.
- Calibrate equipment and validate data during installation and regularly thereafter to ensure robust and reliable data.
- Perform quality assurance and control checks on the data before using it.
- Use a web or cloud for data storage to avoid loss.
- Keep both raw and adjusted or cleaned data to help document cleaning processes.
- Share data with other jurisdictions to further promote use and collection.

- Develop visualizations and performance metrics based on data to generate further interest in and demand for pedestrian data.

Our research also revealed a number of potential topics for further research:

- Understand and study pedestrian travel patterns.
- Develop adjustment factors and create factor groups for pedestrian travel.
- Continue to test and evaluate new pedestrian counting technologies.
- Establish quality assurance and control standards for pedestrian count data.
- Develop site selection criteria for continuous and short-duration count locations.

PEDESTRIAN COUNT DATA COLLECTION EQUIPMENT

When counting pedestrians, it is critical to choose the right technology for the count purpose, setting, and duration. Once the appropriate technology has been chosen, proper installation, calibration and validation (for automated equipment) are essential to ensuring good quality counts. Agencies also need to assess how best to strategically allocate limited resources when managing counting programs.

In general, counting pedestrian traffic at constrained points and in pedestrian-only environments helps to reduce error from occlusion and potential errors due to automated counters capturing bicyclists or other non-pedestrians. However, many facilities on which agencies will want to collect count data do not meet these criteria. Specific recommendations for automated counting by facility type are listed in Table 6-1.

Table 6-1. Specific Recommendations for Automated Counting by Facility Type

Facility	Intersection / Segment?	Automated Technologies Used	Specific Recommendations
Sidewalks (and pedestrian-only trails)	Segment	Passive infrared, active infrared, automated counts from video	Point infrared emitters toward a wall or another non-reflective, non-moving surface, and do not install infrared receivers in direct sunlight. Video is best collected from above to prevent occlusion.
Crosswalks	Intersection	Automated counts from video, pedestrian push button actuation	Video is best collected from above, if possible, to prevent occlusion.
Shared use paths	Both	Passive or active infrared in combination with inductive loops or pneumatic tubes to distinguish cyclists; pressure pads (if unpaved)	If tubes used, small diameter are best, to reduce trip hazard and increase accuracy.
Vertical transportation	Segment	Passive infrared, active infrared, pressure pads, thermal cameras	Install equipment in a secure location to prevent vandalism.
Overpasses and Underpasses	Segment	Passive or active infrared, alone or in combination with inductive loops or pneumatic tubes to distinguish cyclists	It can be difficult to place equipment on bridge decks; an alternative is to place it at approaches.
Plazas	General activity	Wi-Fi/Bluetooth detectors	Manual counts can be used to track paths through plazas or conducted at points of entrance.
Road shoulder*	Segment	None	Further research is needed
Pedestrians crossing not at crosswalks*	Segment	Infrared motion-activated cameras	Further research is needed.

* Manual counts from video is probably the most viable option for these facilities because the ability to fast forward makes to process of counting infrequent events more efficient. Infrared motion-activated cameras like those used to monitor wildlife crossings can also be used.

In addition, surrogate measures of pedestrian counts such as Bluetooth and Wi-Fi counting and pedestrian push button actuation logs may provide useful supplements to pedestrian count data, to help improve estimates of pedestrian volumes where counts are not collected.

Since technologies are continuously evolving, future innovation and development may bring new or improved technologies to the field of pedestrian counting that my improve data collection and improve pedestrian traffic counting. Continuing to watch and study these developments will be helpful for the future of pedestrian traffic counting.

STRATEGIC CONSIDERATIONS FOR PEDESTRIAN COUNTING PROGRAMS

Though a variety of count types, durations, locations, and technologies are necessary in order to collect valid and meaningful pedestrian data, the majority of pedestrian counts are still short-duration, two-hour manual counts. The best practices listed below will help to broaden the variety of pedestrian counts conducted and enhance the quality and usefulness of the data collected:

- Expand the use of “mid-range” (multi-day or multi-week) counts to reduce associated estimation error rates.
- Beware of the inherent pitfalls, primarily estimation inaccuracies, associated with partial day pedestrian counts.
- Rotate "mid-term" automated counter(s) around the network in order to determine what type of pattern exists at each site (commute, mixed, non-commute, etc.) and use the findings to choose the right set of temporal adjustment factors and to adjust the time during which manual counts are conducted to match the actual peak hour.
- Use manual short-duration counts to validate results of mid-term and continuous counts.

Given that undercounting rates and resulting bias compensation factors are typically higher for pedestrian counts than with other modes, funding is needed for research that documents the error rates associated with various equipment types or develops broadly applicable bias compensation factors.

DATA MANAGEMENT PROCEDURES

Quality Assurance and Control

Automated data collection is necessary to inform comprehensive pedestrian plans and analyses. Many resources identify quality assurance procedures for automated motor vehicle count data that can also be applied to pedestrian data, but further work is needed to develop best practices that account for the unique nature of pedestrian data, including:

- Developing guidelines for data completeness: Less complete pedestrian count data, such as two-hour counts, can still be useful for some purposes such as early in the planning process for a new facility, while high data completeness is needed for other purposes such as facility-specific safety analysis.
- Identifying procedures to verify and calibrate automated equipment using manual ground truth counts on installation, and annually thereafter for continuous count stations.
- Developing automated validation criteria for pedestrian counts, such as comparison with historical counts, multiple days with consecutive zeros, missing data, checks for outliers, and more than three repeating values and that all data be checked for proper format and missing data and inspected manually by a trained professional. Current state of the practice is not well

established and can result in flagging too much of the data as errors due to the highly variable nature of pedestrian counts.

- Developing bias compensation factors to account for undercounting due to occlusion and other equipment issues.

Standard Metadata

The TMG Chapter 7 provides a standard list of metadata. These are documented in detail in the station record description in TMG Section 7.9, as well as in the count record in TMG Section 7.10. Other data archives also give standard metadata. Below is a list of standard metadata (relevant TMG field names given in parenthesis).

- Station location, a text field describing the count location, include roadway name (Station Location)
- Station number, in format used by collecting agency (Station ID)
- Pedestrian facility type (Crosswalk, Sidewalk, or Exclusive Facility)
- Latitude and longitude (Latitude, Longitude)
- Direction of pedestrian travel (Direction of travel)
- Mode of travel (Type of count (bicycle/pedestrian/both))
- Weather (Precipitation, High temperature, Low Temperature)
- Start date and time (Year of Count, Month of Count, Day of Count, Count Start Time for This Record)
- Count interval (Count Interval Being Reported)

Data Analysis

To standardize pedestrian count data in a way that simplifies data collection and maximizes comparability with motor vehicle traffic monitoring practice, the following standard summary metrics are suggested:

- Annual average daily pedestrians (AADP) or average daily pedestrians (ADP) if continuous counters are not available.
- Weekend and weekday AADP.
- Average pedestrians per hour of the day and day of the week.
- Monthly average daily pedestrians (MADP).
- Year over year change in pedestrian volume.
- Maximum hourly count for the year and location (at short-duration count sites). Usually maximum is listed since pedestrian counts are sparse, but as additional pedestrian data become available, the 30th highest peak hour for a given year at a given location (for continuous count sites), similar to motor-vehicle data, might be a metric of greater interest when it can be computed.

In order for these metrics to become standard practice, more research and guidance are needed to create adjustment factors that will help practitioners create summary metrics based on counts from different locations, dates, and times.

RECOMMENDATIONS

Based on the information reviewed in this report, below are some practical recommendations for practitioners who seek to count pedestrians and monitor pedestrian travel patterns.

- If planning to estimate overall levels of pedestrian activity over time and across a network, count pedestrians at BOTH short-duration and continuous count sites.
  - If temporal variation is of interest (to show growth in use over time, for example), continuous pedestrian counters are needed.
  - If spatial variation is of interest (to show how pedestrian sidewalk travel varies by block face, for example), short-duration counts are desirable.
  - If both temporal and spatial variation of pedestrian traffic are of interest, BOTH short-duration and continuous counts are needed.
- Different QC for low volume sites than high volume.
- Validate equipment at installation and regularly thereafter.
- Expand the use of "mid-range" (multi-day or multi-week) counts to reduce associated estimation error rates.
- Beware of the inherent pitfalls, primarily estimation inaccuracies, associated with partial day pedestrian counts.
- Rotate "mid-term" automated counter(s) around the network.
- Compute bias compensation factors (e.g., occlusion adjustment factors) to compensate for limitations to equipment and locations. This is especially important for pedestrian count equipment which tend to undercount and uncorrected, could mislead policy makers.

If you find that you cannot get counts but have access to other data sources (e.g., pedestrian pushbutton data), you may be able to develop suitable measures from those sources, but that is not addressed in this document.

COUNTING PROGRAMS	
Literature Reviewed	**Key Points**
National Bicycle and Pedestrian Documentation Project, 2003	▪ First national effort to provide consistent procedures and forms for counting ▪ Focus on short-duration counts
Cottrell et al., 2003	• Outlines elements of a pedestrian data counting program
Schneider et al., 2005	• Presents case studies of 29 communities collecting bicycle and pedestrian data • Identifies benefits and challenges with collecting nonmotorized data

7. APPENDIX A – ACADEMIC PAPERS SUMMARY

Baker et al., 2012	• Sixteen states had well established bicycle and pedestrian programs with some traffic monitoring programs • Eighteen states had some bicycle and pedestrian programs but no traffic monitoring programs • Sixteen states had no evidence of programs • Colorado, Vermont and Washington identified as leaders in counting nonmotorized traffic
TMG, 2013	• New chapter on counting nonmotorized traffic • Describes the steps in establishing both short-duration and continuous data programs • Specific technologies and application of them in counting detailed
Lindsey et al., 2014	• Reviews progress in establishing continuous and short-duration count counting programs in Colorado, Minnesota and Oregon
Minge et al., 2015	• Summarizes the steps for establishing a bicycle and pedestrian data program

COUNT DURATION AND TIMING	
Literature Reviewed	**Key Points**
NBPDP, 2003	• Provides factors for estimating bicycle and pedestrian volumes • Provides factors for combined pedestrian and bicycle counts on paths
Nordback et al., 2013	• Short term counts were used to develop factors to estimate AADB • Recommend one week of continuous counts as being optimal for reducing AADB error • To reduce variability, counts should be conducted between May-October
El Esawey, 2014	• Counting in summer months, produced the lowest estimation error • Counting for one month, significantly improves estimation accuracy
Hankey et al., 2014	• In temperate zones, counting is recommended in April-October • Counting for at least one week is recommended, although in some cases acceptable error rates may be obtained with 24 hour counts

COUNT SITE SELECTION	
Literature Reviewed	**Key Points**
NBPDP, 2003	• List site selection criteria for short-duration site locations
TMG, 2013	• Short-duration count locations are chosen either due to practitioner interest or locations with high activity levels • Continuous count selection is driven by the need for representative locations and if separate bicycle and pedestrian counts are required
NCHRP 797	• Four approaches towards selecting sites: random, targeted, representative and control
Jackson et al., 2015	• Site selection is performed by contacting agencies, developing site selection criteria, evaluating and prioritizing site selection recommendations and conducting virtual and on-site audits.

TECHNOLOGIES				
Technology	**Reviewed Literature**	**Advantages**	**Disadvantages**	**Key Results**
MANUAL COUNTS IN-FIELD **These counts are performed manually in the field using data sheets, clickers or count boards.**	▪ FHWA, 2013 ▪ Ryus et al., 2014 ▪ Diogenes et al., 2007	▪ Lack of installation costs ▪ Applicability to all sites ▪ Portable ▪ Flexibility to gather additional information such as non-compliance ▪ Can be used to validate automated counts	▪ High cost ▪ Applicable for short-duration counts only ▪ Accuracy is dependent on data collector training and fatigue	▪ Diogenes et al. found that pedestrian counts obtained in field manually were lower than counts obtained manually using video. ▪ Observed undercounting rates were between 8%-25%. ▪ No relationship was found between accuracy of in-field counts and higher pedestrian flows.
MANUAL COUNTS FROM VIDEO **Counts are obtained from video footage manually using sheets, computer or a count board**	▪ FHWA, 2013 ▪ Ryus et al., 2014 　○ Diogenes et al., 2007	▪ Ability to speed up or slow down video ▪ Video can be viewed later and used for reconfirmation ▪ Single data collector can reduce data from multiple sites ▪ Flexibility to gather additional information such as gender and non-compliance	▪ Useful only for short-duration counts ▪ Labor intensive process for data reduction ▪ Potential for theft ▪ Frequent field visits may be required for swapping batteries and storage cards ▪ Requires a pole for mounting and installation	▪ Diogenes et al. found that manual counts from video were more accurate than counting in the field.

TECHNOLOGIES				
LASER SCANNERS **These devices emit pulses and analyze the reflections of pulses to detect pedestrians**	▪ Schweizer, 2005 ▪ Bu et al., 2007	▪ N/A	▪ Commercially unavailable	▪ Bu et al. reported difficulties in inclement weather
AUTOMATED VIDEO COUNTS **Algorithms that use computer vision techniques and visual pattern recognition**	▪ FHWA, 2013 ▪ Ryus et al., 2014 ▪ Ismail et al., 2009 ▪ Li et al., 2012 ▪ Zangenehpour et al., 2015 ▪ Zaki et al., 2014	▪ Minimal labor is needed for data processing ▪ Cameras are portable and can be used at many sites ▪ Recorded video data could be used for other purposes	▪ Useful for short-duration counts because of storage limitations ▪ Limited commercially available products	▪ Li et al., found 5% undercounting error between automated and manual counts of pedestrians ▪ Zangenehpour et al., obtained 88% classification accuracy for bicycles and pedestrians, which was lower than vehicle classification accuracy ▪ Zaki et al. found a 13% error rate for counting pedestrians from trajectories
PRESSURE OR ACOUSTIC PADS **Pressure pads record changes in weight on the pad; acoustic pads detect the passage of energy waves**	▪ FHWA, 2013 ▪ Ryus et al., 2014	▪ Primarily used for unpaved trails, suitable for long term counting purposes ▪ Pressure pads are able to distinguish between pedestrians and bicyclists, acoustic	▪ Since pads have to be installed in the ground, they are not recommended for locations which experience freezing conditions during winter	▪ Accuracy has not been tested

TECHNOLOGIES				
through the ground		pads can count pedestrians only		
PASSIVE INFRARED **These devices detect and count pedestrians and bicyclists by detecting differences between the thermal energy emitted by people and the background**	▪ FHWA, 2013 ▪ Ryus et al., 2014 ▪ Schneider et al.,2009 ▪ Schneider et al.,2009 ▪ Ozbay et al., 2010 ▪ Jones et al., 2010 ▪ Montufar et al., 2011 ▪ Greene-Roesel et al.,2008	▪ Portable and easy to use ▪ Battery powered, does not need external power source	▪ Cannot distinguish between pedestrians and bicyclists ▪ Occlusion with groups of people ▪ Higher ambient temperatures may impact accuracy	▪ NCHRP 797 found undercounting rates of -3.1% and -16.7% ▪ Schneider et al. found undercounting rates between 1% and 20%, undercounting during high volume and low volume conditions, rate of undercounting not related to pedestrian volumes ▪ Ozbay et al. observed undercounting rates between -5.26% and -27.9% ▪ Jones et al. found undercounting rates of -21% and -15% ▪ Montufar et al. found the infrared device missed the least number of calls,

TECHNOLOGIES				
				however it recorded a high percentage of false calls
ACTIVE INFRARED **These devices use an emitter and a receiver located on opposite sides of a path or sidewalk, with a count being recorded when the beam is broken.**	▪ FHWA, 2013 ▪ Ryus et al., 2014	▪ Portable and easy to install ▪ Battery powered ▪ Error is linear, so correction factors can be applied	▪ Occlusion with groups of pedestrians ▪ Cannot distinguish between pedestrians and bicyclists	▪ NCHRP 797 found undercounting rate of -9.1%, rate of undercounting increases as volumes increase ▪ Jones et al. also found evidence of undercounting between -25% to -48% for pedestrians, with higher rates of undercounting seen for larger volumes

COUNT ARCHIVE	
Literature Reviewed	**Key Points**
NBPDP, 2004	▪ Accepts all count data, however easy electronic access to the count data is not available
FHWA, 2013	▪ Provides a national standard format for count data storage ▪ Can be used for both portable and continuous data ▪ Provides easy national reference dataset and data comparison for local, MPO and State DOT counting programs and sharing of such data ▪ Allows for historical data trending, weather influences and a robust set of site characteristics
Los Angeles County Clearinghouse	▪ Accepts 2 hour bicycle manual count data ▪ Provides easy online access through a web interface. ▪ Cannot accept continuous count data or pedestrian data
DVRPC Pedestrian and Bicycle Counts	▪ Map displays pedestrian and bicycle count data within DVRPC region ▪ Also provides AADB and AADP estimates
Bike-Ped PORTAL	▪ First national archive for nonmotorized data ▪ Is set up to accept continuous and short-duration data ▪ Provides easy online access to the count data

COUNT QA/QC	
Literature Reviewed	**Key Points**
FHWA, 2013	▪ Defines quality control checks used in TMAS 2.7 ▪ Four types of quality control levels: fatal, critical, caution and warning flags ▪ Import, export, query, delete and reporting of data ▪ National quality control adjustable by site
Turner and Lasley, 2013	▪ Provide quality control and validity checks based on outliers and percent deviation
Ryus et al., 2014	▪ Recommends validation and calibration of counters for clean data ▪ Recommends the development of correction factors based on technology and site characteristics where applicable.

8. APPENDIX B - TECHNOLOGIES

Manual Counts In-Field

Pedestrians may be counted in the field by observers using data collection sheets, clickers or count boards. In the last few years, smartphone applications have also emerged for manual pedestrian counts. Manual in-field counts are typically used to collect short-duration counts, and can yield very accurate information if the data collectors are well trained. They are often used to validate automated count data. The advantages with manual counts include the ability to gather additional information, such as gender and compliance with traffic signal displays. Manual counts do not involve any installation costs and are applicable to all sites and users.[175] Disadvantages with manual counts include the inability to collect data over a longer time frame and the possibility of inaccuracies and biases in data collection, particularly if counters are not well trained.[176] Data verification is also difficult with in-field manual counts, and it can be harder to conduct manual counts at locations with high pedestrian volumes.

Manual Counts In-Field – Findings

Diogenes et al. compared manual counts where data was entered on sheets, manual counts that used clickers to record pedestrians, and manual counts from video. They found that manual counts using sheets or clickers underestimated pedestrian volumes by between eight and 25 percent.[177] They also found that accuracy was worse during the beginning and end of the data collection period, which could perhaps be attributed to lack of familiarity in the beginning and fatigue at the end.

Manual Counts from Video

Manual counts can also be taken from video collected in the field. As with in-field counts, data from video-based counts can be entered using data collection sheets, clickers, count boards or smartphone applications. These types of counts are often used as ground truth in various studies or as a way to validate counts from other types of equipment.[178] Manual counts from video are typically used only for short-duration counts as this is a labor-intensive way to collect data.[179] Video-based manual counts have similar advantages to in-field counts, including the ability to gather additional information such as gender and compliance. The main advantage of using video compared to in-field counts is that video can be reviewed at staff's convenience, and the footage can be sped up for low-volume areas or slowed down for high-volume locations, all of which can increase accuracy. The recorded data can be used for additional purposes. The disadvantages of video-based counts include installation time to set up the equipment and ensure that the equipment is working, susceptibility of the equipment to vandalism and theft, and the possibility of poor video footage.[180]

Manual Counts from Video – Findings

Diogenes et al. found that manual counts using video were more accurate than other forms of manual counts, as discussed above.[181] No other studies evaluating the accuracy of manual counts (in-field or video) were found.

Automated Counts from Video

Pedestrian counts can be automatically generated from video footage using computer vision techniques and visual pattern recognition. This technology has been rapidly evolving in the last decade and, according to several webinar participants, is growing in popularity since it is not as labor-intensive as manual counting. Cameras are portable and can be used at multiple locations, but due to limitations on space for long-term installations this technology may be best suited for short-duration counts. The recorded data can also be used for other purposes such as facility evaluation and user behavior studies.

Automated Counts from Video – Findings

Various studies evaluating automated video counts have found errors ranging from five to 13 percent when counting pedestrians.[182,183,184,185]

Passive Infrared

Pedestrians and bicyclists can be detected by passive infrared devices, which measure the difference between background thermal energy and heat emitted by people passing in front of the counter.[186] These devices are typically placed on the side of crosswalks or trails. They are portable, battery-powered, and relatively easy to install, which makes them well-suited for continuous counting of nonmotorized users. Limitations with this technology include the inability to distinguish between bicyclists and pedestrians, potential undercounting for groups of pedestrians due to occlusion, and inaccuracies on hotter days.[187] To minimize occlusion, the TMG recommends placing passive and active infrared counters at constrained locations where pedestrians are more likely to walk single-file.[188]

Passive Infrared – Findings

Many studies found that passive infrared devices were prone to undercounting.[189,190,191,192,193,194] NCHRP 797 tested two different passive infrared sensors and found undercounting rates between 3.1 and 16.7 percent.[195] Schneider et al. found undercounting rates between one and 20 percent, with devices undercounting during both high and low volume conditions.[196] Ozbay et al. also found undercounting rates with passive infrared devices ranging between 5.26 and 27.9 percent.[197] Montufar et al. tested three types of automated pedestrian detectors – a passive infrared and stereovision curbside detector, a passive infrared curbside detector and a microwave detector in cold temperatures.[198] They found that the infrared device had the highest sensitivity (percentage of pedestrian crossings detected successfully) and lowest selectivity (percentage of actuations triggered by actual pedestrians instead of false actuations) among all the tested devices. Selectivity rates for all three devices were less than 50 percent.

Active Infrared

Active infrared devices include an emitter and a receiver located on opposite sides of a path or sidewalk, and record a count when the when the beam between the emitter and receiver is broken.[199] These devices offer similar advantages and disadvantages to passive infrared devices: they are portable and battery powered, but cannot distinguish between pedestrians and bicyclists and are prone to occlusion errors when a group of pedestrians crosses in front of the sensor. However, active infrared devices have a narrower detection zone than passive infrared sensors, and can be more challenging to install since both the transmitter and the receiver need to be mounted and aligned properly with a clear line of sight.[200] Active infrared also has a higher risk of false positives due to objects such as vehicles, insects, and falling leaves.[201] One advantage of active infrared compared to passive infrared is that they have less accuracy at high volumes, which means that correction factors can be applied to generate accurate results.[202]

Active Infrared – Findings

Jones et al. found undercounting rates between 25 and 48 percent for pedestrians, with less accurate results at higher volumes.[203] NCHRP 797 tested one active infrared device and found an undercounting rate of 9.1 percent, and that the rate of undercounting increased as volumes increased.[204]

Radio Beam

As with active infrared, radio beam devices employ a transmitter and receiver placed on opposite sides of a path or trail and register a count when the beam between the two is broken.[205] These devices are portable, easy to install, battery powered and can be used for continuous counts. It is possible to use devices with multiple frequencies to distinguish between pedestrians and bicyclists, but occlusion errors are a possibility with radio beam counters. Installation can be more challenging, since radio beam devices require posts or other fixed objects along both sides of a facility for mounting purposes.

Radio Beam – Findings

There has been very limited research on radio beam technology. NCHRP 797 tested two different products, one that counted bicyclists and pedestrians on two separate frequencies and another that counted them in combination. The report found the Average Percent Deviation (APD) was 31.2 percent undercount for bicycles and 26.3 percent undercount for pedestrians for the product that counted the modes separately. For the combination product, the APD was obtained as 3.6 percent undercount.

Thermal Cameras

Thermal cameras generate infrared images that capture body heat.[206] Like other video counting technologies, they can potentially be used to collect data for manual or automated counts, but unlike traditional video cameras, they are not affected by changes in ambient light, so can be used to capture pedestrians at night. Although thermal cameras are available commercially, there haven't been any academic studies reviewing the cameras' ability to capture pedestrians.

Thermal Cameras – Findings

No studies have tested the accuracy of thermal cameras in counting pedestrians, but during the interview process one vendor mentioned that these devices were being used in France to count pedestrians[207].

Laser Scanners

Laser scanners emit pulses in many directions and analyze the reflections of the pulses to determine if bicyclists or pedestrians are present.[208] These devices require an external power source and have primarily been used indoors. They cannot distinguish between bicyclists and pedestrians and are generally of two types – horizontal or vertical. Horizontal scanners require locations with no obstructions, whereas vertical scanners are mounted above the detection area.

Laser Scanners – Findings

Few studies have evaluated the accuracy of these devices. Bu et al. reported difficulty while counting with laser scanners in poor weather conditions.[209]

Pressure and Acoustic Pads

Pressure pads detect changes in weight when pedestrians step on the pad. Acoustic pads detect the passage of energy waves through the ground caused by pedestrians and bicyclists.[210] Both of these devices require the counting element to be placed at or near the detector area, are battery-powered and are typically concealed under the ground, which makes them resistant to vandalism. While pressure pads can count and distinguish between pedestrians and bicyclists based on the pressure applied to the sensor, acoustic pads only count pedestrians.[211] However, users must pass directly over the sensor in order to be counted. These devices are typically placed on unpaved trails and are used for continuous counting. They are also not feasible for locations with severe winters, where the ground freezes, nor for paved paths and trails.

Pressure and Acoustic Pads – Findings

No research studies have tested the accuracy of these devices.

Surrogate Measure: Bluetooth and Wi-Fi Counting

Counting pedestrian traffic using Bluetooth and Wi-Fi detection is an emerging area of research. This is a surrogate measure because it does not count all pedestrians, but those who carry with them certain active, operating Bluetooth or Wi-Fi enabled devices, such as cell phones and laptops.[212] Bluetooth or Wi-Fi detection can capture travel times by matching Media Access Control (MAC) addresses, which are unique identifiers used for Bluetooth or Wi-Fi enabled devices, across several readers. However, this technology cannot distinguish between bicyclists and pedestrians. Since this technology can only capture a small sample of the population, it is more applicable for discerning trends than conducting actual counts.

Surrogate Measure: Bluetooth and Wi-Fi Counting – Findings

Malinovskiy et al. investigated the possibility of using Bluetooth readers to track pedestrians at two locations.[213] They found that obtaining sufficient sample sizes was an issue.

Surrogate Measure: Pedestrian Push Button Actuation Logs

Another potential technology from which pedestrian traffic counting data can be collected is pedestrian pushbutton actuations at signalized intersections. This approach is limited to areas where pedestrian pushbuttons are used for signal actuation. This is a surrogate measure because only one actuation per signal cycle is recorded per phase, irrespective of the number of crossing pedestrians. Therefore, it can be considered as a proxy for pedestrian demand activity at an intersection. However, studies show a correspondence with count volumes and the utility of pedestrian actuations as a measure of pedestrian activity at intersections).[214,215] This approach can provide valuable information on pedestrian traffic activity levels in suburban areas where counts have not been conducted. Since existing infrastructure is used to collect these data, costs can be very low.

Surrogate Measure: Pedestrian Push Button Actuation Logs – Findings

Kothuri et al. recorded pedestrian actuations at signalized intersections in Portland, OR to understand the pedestrian activity levels and trends. They found that pedestrian activity varied greatly by time of day.[216] Figliozzi et al. observed a linear relationship (ratio of 1.2 pedestrians per actuation) between pedestrian phase actuations to the number of crossing pedestrians at an intersection.[217]

Having a table like is in the TMG would be helpful to see the technology and findings from each for a quick reference, this same reference may also then be included in the 2016 TMG Supplement.

9. APPENDIX C – WEBINAR SHARING DOCUMENT

Name and/or organization	What problems have you encountered in trying to count pedestrians?
Sirisha Kothuri, PSU	Pedestrians don't cross at fixed locations, lack of technologies for counting peds.
Christiaan Abildso, Morgantown WV	Have to identify a corridor to count; some cost issues; some issues on my side with user error when technology changes
Benjamin Krumenauer, ECWRPC	Thus far we have had great success using a variety of counting methods including remote video, field (to a lesser extent) and Infrared counters. The biggest issue we have had is the shear size of our urbanized region. It is true that a pedestrian will not always follow a prescribed route, but for us it is the limited number of counters (6 total) and the myriad of locations needed.
Lee Kim, AKRF (NYC)	Duration of the counts (price), high volume locations (need more counters). One of the crosswalk that we had to examine had more than 5000 pedestrians per hour. The manual counters were overwhelmed.
Diniece Peters, NYCDOT (NYC)	Our counts are primarily collected manually and is often very difficult to manually count pedestrians in dense cases where hourly volumes exceed 6000-7000 pedestrians on a link/facility. (Ex. Sidewalk near Times Square)
Tram Truong, Greensboro MPO, NC	We used Eco Counter Pyro Box to count pedestrian. One of the incoveniences of this equipment is that we have to find a location with a pole close to a curb to put the counter on. It limits the locations that I want to count.
Sarah O'Brien, ITRE	On behalf of NCDOT's Non-motorized Volume Data Program: occlusion, bypass errors
Ariana Jeske, Prein & Newhof Grand Rapids, MI	Our interest has been in predicting users of non-motorized paths to justify enhanced crossing options. Not having a facility to count has been a barrier to that. Identifying reliable long term methods for counting bikes and peds on non-motorized paths has been difficult. Cost effectiveness of labor has been a hurdle too.
Camille Jackson, Walk San Francisco	Time frame of doing counts. How long to do you need to do counts it for for accurate data? In addition how to count accurately for heavy pedestrain flows?
Katelyn DiGioia, GDOT	To date we have only done counts to justify crossing treatments (staff time is a challenge); we are conducting a research project to develop an automated mid-block pedestrian counter, but will only have one device on hand for the entire state until we can deomstrate need for more. I do not know how to tackle a statewide estimation of ped volumes.
Eric Tam, GNEC	For shared-use facilities (Pedestrians + Cyclists), is there a preferred method to effectively differentiate between the two modes in automated counts?
Don Bennett, City of Wilminton NC	The biggest issue we have is counting latent pedestrian demand, ie how many peds would like to walk but do not because of a major perceived barrier

Name and/or organization	Tell us about your pedestrian counting practices, including technologies and locations.
Krista Nordback, PSU	We've used passive infrared sensors for short duration counts on sidewalks and paths.
Bo Ling, Migma Systems	Migma developed a ped counting system that can automatically count the number of pedestrians walking across the crosswalks, in both directions (e.g., north or south). Pedestrians walking in large groups can be counted with accuracy over 95%. Its technology is a combination of stereo camera and laser scanner. The system was developed under FHWA funding. Information can be found at: http://www.migmapd.com/migmapedcount.htm.
Christiaan Abildso, Morgantown WV	We've used TRAFx infrared sensors on our local trail system (https://www.trafx.net/) and will be installing eco-counter multi system at a key trail/road intersection in the coming year (http://www.eco-compteur.com/en/)
Benjamin Krumenauer, ECWRPC	we have six (6) passive infrared counters that have a measured ranged of 25ft made by TRAFx and two (2) pneumatic tube counters made by Eco-counter. This way we can seperate the bicycle counts from the overall counts. We have had great success using the two options and the report programs are very handy. We also utilize the regions DOT and local municipal traffic camera systems to verify remote counts and conduct rapid counts of targeted areas. We have used manual counts in the field, but compared to the other forms, manual counts are far less efficient.
Lee Kim, AKRF (NYC)	We have used Miovision (video data collection) and placemeter (using smartphone sensors) in New York City as well as manual counts. Pedestrian counts are usually done for crosswalks, corners, and sidewalks at selected locations.
Diniece Peters, NYCDOT (NYC)	Pedestrian counts are collected manually as well as with other newer technologies such as MioVision, and Placemeter. We typically collect data at corners, crosswalks, and sidewalks
Tram Truong, Greensboro MPO, NC	We use MioVision and Eco Counter Pyro box for short counting period and Eco Pyro Post for permanent counting to count pedestrian on sidewalk. Parks and Rec Department use TrafX to count pedestrian and bicycle on greenway. We cooperate with Parks & Rec to put the Eco Pneumatic Tube at some locations on greenway so they can differentiate bicycle and pedestrian. The tube is installed for short term only (1-1.5 month).
Katelyn DiGioia, GDOT	To date we have only done counts to justify crossing treatments (staff time is a challenge); we are conducting a research project to develop an automated mid-block pedestrian counter (uses cameras.
Robert Nelson, IL DOT (D5 East Central IL)	We have just started taking ped / bike counts. We do manual counts and use MioVision video.
Kristen Maddox O'Toole, Alta Planning (Chicago)	We used TrailMaster active intrared counters to count pedestrians in Columbus, OH. Counters were placed in downtown locations and on shared-use paths. Equipment was deployed for 14 days at a time. Some needed to be adjusted if counters reached capacity.
Peter Ohlms, Virginia DOT Research Division	Miovision at an intersection; manual counts with clipboards at screenline locations. Both were short-term, 4-12 hours, for multiple days.

Name and/or organization	Tell us about your pedestrian counting practices, including technologies and locations.
Laurent Fournier, Michigan DOT	Miovision at intersections and for a few specific bike lanes. We are currently working on expanding our counting capability (testing, planning)
Camille Jackson, Walk San Francisco	Have done manual traffic counts for 2 hours at 15 minute intervals at an intersection. And have used eco - counters to count people using/accessing open spaces in San Luis Obispo, CA.
Donnie Miller, City of Bettendorf, IA - Bike/Ped Coordinator	Our local MPO, Bi-State Regional Commission is doing trail counts for us using TRAFx counters. We are on our third count cycle and preparing to compile data to compare like months and times. One problem we are having is that we are along the Mississippi River and are seeing a lot of animal data that we are having a hard time extracting from the data as we have not done any manual counts to get the actall AADT and MADT.
Taylor Lonsdale, Western Transportation Institute, Bozeman, MT	I have been utilizing CounterPoint mobile app on a trial basis. It is a simple mobile app that enables many users to do screen line counts that include bikes, peds, and motor vehicles. Counts can be done in various time increments. Once a count location is established, other users can conduct counts at those locations. www.counterpointapp.org
Don Bennett, City of Wilmington NC	we use the CCTV video from our signal system and a DVR, remote deployable video systems, we also log the number of WALK cycles our traffic signals run
Mid-America Regional Council (MARC) - Kansas City, Mo.	We have 4 passive infrared counters, 2 pneumatic tube counters, and have used Miovision video processing at some locations.[Stephen Lachky]
Stanislav Parfenov, Placemeter (vendor)	Placemeter uses camera streams to convert them into pedestrian, bicycle and vehicular counts. All you need is a camera
Keith Sorenson, Charlotte, NC	We are using video at all intersections to count pedestrians and the County is using eco counters on greenways
Barb Mee, Ashville, NC	We are currently doing annual 2-hour counts by volunteers, and we routinely include peds and bikes when we order 12-hour counts. Our MPO can do 2 counts a quarter for us using Pyro counters.
Jon Kaplan, Vermont	We have primarily used Eco-counter pyro and manual counts. Most counts have been on sidewalks and shared use paths. Have also started doing manual counts in 2 6 hour shifts at intersections
Lisa Austin, Minnesotta	eco-counter ir, trail master, chambers, manual
Amy Lewin, City of Fort Collins, Co	we have manual intersection counts at signalized intersections every 1-2 years (bikes, peds, cars), 12+ semi-permanent counters on trails (bikes/peds combined), and one permanent counter on a trail (bikes and peds counted separately), as well as annual counts on trails of bikes and peds conducted by volunteers
Don Bennett, City of Wilmington NC	we have not used yet, but Sensys pucks in bike lanes could be run back to signal cabinets for controller logging. [Donald Bennett
Sarah O'Brien, ITRE	on behalf of NCDOT's non-motorized volume data program: we use passive infrared sensors. Currently, there are 13 continuous count sites (comprised of 22 stations to get screenline counts) and 22 short duration count stations. We are expanding across the state with plans to install another ~30 CCS sites and 50 SDC stations. Locations include a mix of urban, rural, university sites (sidewalk and shared use path) that show different TOD, DOW, and seasonal travel patterns We use video cameras (post-processed manually) to validate the CCS counts

Name and/or organization	Describe your short duration and continuous pedestrian count programs.
Christiaan Abildso, Morgantown WV	We have had infrared sensors at 3 locations on our trail system for the last 9 months or so (but lost 3 months of data due to user error)
Benjamin Krumenauer, ECWRPC	I developed a counting program and procedure that outlines two duration formats: Option one is based on a three day count length and aligns closer with WisDOT. The second option is based on a seven day count length and captures a higher volume of users with full weekend and week days counted. we tend to follow the seven day format as it gets a statistically more significant volume of users. Our count stystem is based on mobile technology so we can maximize its utility throughout the three MPO area. Several area municipalities have installed permanent Inductive Loop and IR systems, some of which have been measuring with no major issues for ten years.
Lee Kim, AKRF (NYC)	Usually we do ped counts for three peak analysis periods (AM- 7 to 10, MD- 11 to 2, and PM - 4 to 7). We have not done continuous counts for a project, but are testing out continuous in/out counts at an office building and a deli in Mid-town Manhattan as a pilot program for trip generation study.
Diniece Peters, NYCDOT (NYC)	We typically collect pedestrian counts for peak hours (periods) of vehicular traffic unless the pedestrian peak occurs at a different time than the vehicular peak. Certain screen line locations are collected annually.
Tram Truong, Greensboro MPO, NC	We participated in Permanent Counting Program with NCDOT to develop factors. For short term counting, we use MioVision to collect 12-hour counting (7AM - 7PM) at intersections and Pyro Boxes to collect data onsidewalk.
Robert Nelson IL DOT (D5 East Central IL)	Manual counts - 12 hours. Miovision counts - 24 hours.
Lisa Austin, MN	Many communities in Minnesota do 2 hour counts during the recommended National count days in September. the MN Dept of Health also encourages their health improvement grantees to do counts in September.
Don Bennet, Wilmington, NC	peds counted as needed for projects or special assignments. Ped counts being brought in trough signal system logs are continuous.
Jon Kaplan, Vermont	We have one permanent ped counter on a downtown sidewalk that has been in place for about 9 years. We also have a permanent indicutive loop counter on a shared use path that has been in place for almost two years. Our short duration counts are usually about a week to two weeks or two 6 hour counts of peds at intersections. We are working to come up with factors such as Theo was just discussing
Barb Mee, City of Ashville, NC	volunteers again to collect our annual count data, pdf with results is available on city website.
Sarah O'Brien, ITRE	on behalf of NCDOT's Non-Motorized Volume Data Program: we are developing both elements within this program (which also includes counting bicyclists). We almost have 12 mo. of data from the first batch of CCS's installed, and we have 1 week's worth of data from 22 SDC locations. The program is expanding into the Phase 2 region (which will cover the piedmont area of the state) and bring on a second batch of CCS and SDC data from new sites as well as continue to monitor the initial CCS sites. We also plan to collect additional data in different seasons for the SDC sites. We will be testing the development of adjustment factors and calculating basic statistics as more data are collected to be analyzed. All CCS data go through checks for QA/QC (range check, directional distribution check, empty data check, consecutive zero check). Valid data are put in an Access database in the TMG format for publishing. Correction factors will be developed for each CCS based on a validation process where two days of data pulled from the counter are compared with video data manually processed. Over- or under-counting errors as well as bypass errors are identified, and the results may lead to re-calibration of the equipment, troubleshooting with a vendor technician, testing the sensor alignment and ensuring nothing is blocking the sensor, or other measures. We can also identify the proportion of occlusion and potentially develop a site-specific adjustment factor as needed.

Name and/or organization	Tell us about your pedestrian count data management. How do you manage and share your data?
Krista Nordback, PSU	We have created a bike/ped count archive for the nation's count data. It's at bp.its.pdx.edu right now. We'll make it public soon. For now, we've loaded data from 11 counties in five states so far. It's for segment (screenline) counts only right now, but includes manual and automated data, short duration and permanent counters. If you'd like more information let me know.
Christiaan Abildso, Morgantown WV	I collect the data and send to our trail director, she sends on to a regional rail-trail data collector. I also share our infrared counts with our City Engineer and MPO director. Just me as a volunteer helping out. No public sharing that I'm aware of.
Benjamin Krumenauer, ECWRPC	As a RPC, our data is managed in house through software provided by companies and custom documents I created. The data can easily be tweaked for any situation and when the uses are more extreme, I can place the data on the forms created in house. The data is available to any municipality who requests it and we regularly cc: our local partners to keep them up to date.
Lee Kim, AKRF (NYC)	As consultant we do not "own" the data that we collect, but if t a project goes through the city agency review (i.e. NYCDOT), then we submit the data to NYCDOT and they upload the data to their database.
Diniece Peters, NYCDOT (NYC)	NYCDOT has a Traffic Information Management System (TIMS) which standardizes the way in which the agency processes and posts traffic count data including ATRs, TMC, Pedestrian Counts (segment & intersection), Bicycle Counts (segment & intersection), Vehicle Classification, Spot Speeds, GPS Speed Runs. The system uses a GIS based map to organize the data collected over multiple years and time periods. This management system is also used to request data collection.
Tram Truong, Greensboro MPO, NC	The permanent counting program just started since October last year so the factor development is still developing. The MPO Counting Program is still developing. Currently the data is just shared when I have a request.
Laurent Fournier, Michigan DOT	Turning Movements/Indiv counts currently saved as individual files, shared on our website.Planning to expand our capacity through the modernization of our Traffic Data Management Software.
Katelyn DiGioia, Georgia DOT	To date, counts are only taken in relation to specific infrastructure projects, so data is housed with the project files and not synthsized with other counts or shared.
Robert Nelson IL DOT (D5 East Central IL)	We store data in an Access database and share it with our MPOs. When our MPOs collect data they share with us.
Lisa Austin, MN	: we are relying on the eco-counter data management for now. we are exploring other options to integrate with motorized data.
Jon Kaplan, Vermont	Currently we have one in-house database of manual counts done by or traffic research staff. We also use the EcoCount web based platform for data collected with their equipment. We are just embarking on a project to figure out the best way to combine this data and get it in some format where it will be publicly available. One example similar to the Arlington, VA example is the Chittenden County RPC - they have all their data accessible on their web site
Sarah O'Brien, ITRE	Currently, preliminary data is shared quarterly with the local agencies who installed the counters. (NCDOT purchases the equipment; the local agencies install; NCDOT owns the equipment for 1st 2 years, and then ownership transfers to local agency; local agency responsible for maintenance; NCDOT monitors and manages data). NCDOT (via contract with ITRE) conducts validation processes, QAQC processes, and other data management elements. Once a sufficient amount of data has been collected (i.e. at least 12 months), the checked and valid records will be stored in an Access database in the TMG format and published.

Name and/or organization	What recommendations would you give others that are just starting a pedestrian traffic monitoring program?
Christiaan Abildso, Morgantown WV	Use the data in combination with intercept surveys to quantify the health and/or economic impact of trails (or other ped/bike corridor)
Benjamin Krumenauer, ECWRPC	Make sure that the data collected is properly calibrated and verified. Once the data is collected, format it in a way that will be most beneficial to the target at hand. The data is powerful and always remember that even if the data shows that a future of current facility is not getting the numbers you expected, it is still important data that should be talked about. Make sure to also have a purpose for collecting the data and as Kristen Bennett stated above, tie it to existing metrics and performance measures.
Lee Kim, AKRF (NYC)	1) Communicate with all the stake holders "why" the pedetrian monitoring program is being done. 2) DOCUMENT the reasoning, process, and discussions. 3) Find out what kind of technology is available- to not only give the numbers, but also provide some insights from the data. 4) Be flexible. Even if a certain idea/process was good for one locaiton, it may not apply to another location. Being flexible is important to achieve a better outcome.
Diniece Peters, NYCDOT (NYC)	1) Research available methods/technologies and develop a data collection guide that connects the purpose of project with the right data collection method (manual, video tracking technology, phone sensors, etc), 2) Develop a QA/QC policy to ensure that data is accurate and consistent (historical trends, etc)
Tram Truong, Greensboro MPO, NC	1. Research locations where you are going to conduct the count (high crash location, high use, downtown, upcoming improvement projects, etc.); 2. Research methods and technologies based on your budget, locations, and purpose (short term vs long term); 3. Develop a plan to conduct a count (some locations are different depending on counting time, for example counting around campus should be considered summer break, counting in downtown should be considered holiday since the counting at these period will give you different number); 4. Develop QA/AC method to check data.
Kristen Maddox O'Toole, Alta Planning + Design (Chicago)	Be patient! Equipment installation and recovering data from the devices can sometimes cause headaches. A little patience goes a long way. If installing counters yourself, be prepared to spend extra time in the field. Develop solid QA/QC policies and estimate enough time for "data cleaning" or research for outlying data points. If implementing a program across a city or other large area, scout locations ahead of time and group them in ways that allow you to efficiently reach all devices. Onlookers will be curious. It might be worth it to produce a quick flyer/handout about the project for people who ask. Finally, there are real challenges to being a woman installing equipment in the public way. I think the unwanted attention is something that is not often mentioned with regards to these types of programs.
Sarah O'Brien, ITRE	Get intimately familiar with NCHRP Report 797 and the web only 205 documents as well as the TMG. Talk to subject matter experts and potential peers to understand the diffferent programmatic elements. Create a strategic plan - this should be looking out at least 5 years ahead, if not more. Attend NHI's course on traffic monitoring, or request a non-motorized-specific traffic monitoring course (which some consultants or universities may offer). Make sure you have dedicated staffing resources to handle all the data management aspects -- remember, it's not as simple as throwing a counter out somewhere and collecting the data -- there's much more to it than that!

10. APPENDIX D – INTERVIEWEE COMMENTS

Dr. Robert Schneider, University of Wisconsin, Milwaukee

- Pedestrian patterns are highly variable, localized and influenced by land use.
- Agencies need to devote resources to establish robust pedestrian counting programs.
- Don't assume that pedestrian pattern on the sidewalk is the same as the crosswalk necessarily just because they are adjacent to each other. There can still be some variability between these patterns.
- Pedestrians have many different patterns
  - some commute patterns with mid-day hump
  - many varieties of non-commute patterns
- More research is needed on understanding pedestrian patterns.
- Dr. Schneider's past work focused on providing data for safety studies, counting intersection crossings, not total pedestrians through intersection.
  - Counted primarily on sidewalks using automated counters in order to expand manually collected crosswalk counts at intersections.
  - Asked manual counters to collect other data at intersections (gender, ethnicity, bicycle volumes), but only if it doesn't interfere with pedestrian volume counts.
- Need for crosswalk counts at intersections for safety analyses.
- More thought into how to strategically place counters to get the data we need?
- Need midblock crossing data (between intersections).
- How does facility design impact pedestrian safety?
- Account for occlusion in areas with high pedestrian volumes.

Dr. Greg Lindsey, University of Minnesota

- Focus on pedestrians because they are less studied than bicyclists, while accounting for a larger proportion of travelers.
- Pedestrians have less seasonality than cyclists.
- Pedestrian and bicycle patterns different: for example, at some locations, pedestrian traffic peaks more in a bell-shaped curve at mid-day rather than two peaks (a.m., p.m.) for bicyclists.
- Different factors and variables affect pedestrian travel compared to bicycle travel.
- Need to identify pedestrian specific pattern groups and develop factors
- Should understand how to harvest counts that were collected for other purposes e.g. push button data.

- TMG should include pedestrian specific site selection advice.
- Automated checks of continuous count data do not work well for low volume count locations.
- Occlusion error varies by location and volume.
- Scenario analysis important for understanding consequences of error. How accurate should we be? Depends on what the error would do to our results. Make a table of consequences of error for TMG.
- "Recreational" pattern is better described as "multi-purpose".

Stanislav Parfenov, Placemeter

- Automated video image processing technology to capture pedestrian movements.
- Process surveillance video on the fly without storing to protect privacy.
  - 48 hours of machine learning to train on a new location
  - Manual check of 0.01 percent of video
  - Reasonably priced for continuous stations
  - Looks for head and shoulders triangle
  - Can work at night with sufficient light
- Can be used for continuous or short-duration counts.

Michael Jones, Alta Planning and Design

- Pedestrian plans are not as common as bicycle plans
- NBPDP was set up to offer guidance for communities in a systematic and standardized manner
- Need to understand what the purpose of the counts are to determine where and when to count
- Need survey data to understand overall trends
- TMG should provide guidance for communities to perform different sets of counts based on their purpose
  - Overall walking rate
  - Exposure
- National standards should be developed for QA/QC
  - Should accept some error with pedestrian counts

Jean-Francois Rheault, Eco-Counter

- Pedestrians are less constrained than cyclists, who are easier to capture.

- Infrared, Thermal camera and counting mats are key automated technologies for counting pedestrians.
- In UK and France, national databases exist for bicycle counts, but not for pedestrian counts.
- Business improvement districts are investing a lot of time and money to count pedestrians
  - Data can be used by business district and transportation communities
- Need standard guidance on how to deal with outliers in the data.
- Cloud based storage solutions are more powerful
- Procuring equipment
  - Have someone involved that understands the equipment and process
  - Know and test the accuracy of the equipment that is being purchased

David Patton, Arlington County, VA

- Pedestrians have more free range of movement, so harder to monitor.
- Having a sole provider eases the equipment procurement process.
- Tradeoff accuracy for continuity (automated counters).
- Important to count at alternate locations
  - Tunnels
  - Pedestrian bridges (skybridges)
- Keep both raw data and cleaned data
- Start with counting at high volume locations and also count in low volume locations.
- Need better survey data to accurately characterize pedestrian travel.
- Include guidance in TMG regarding the various brands of equipment.

Aylene McCallum, Downtown Denver Partnership

- It's important to count on every blockface because pedestrian traffic varies so much by block.
- Developers want to know pedestrian traffic on property they are considering developing.
- Keep it simple! Just start counting. Some data is better than none, but know the limitations of whatever method you choose.
- Managing a manual count program is time consuming.
- Automated infrared counters can give a good idea of pedestrian traffic patterns even if there are dramatic undercounts and even though the undercounting rate may vary by time of day.

Lisa Austin, Minnesota Department of Transportation

- There is more interest in using bicycle data, for calculating performance metrics like AADB.

    - Not many requests for pedestrian data
- Pedestrian counts are really important for:
    - Economic development
    - Realtors want pedestrian data to estimate walk score
    - Safety engineers want counts to determine which crossing treatment to install at crossings
- Error rates are higher when counting pedestrians.
- Occlusion is a problem with most equipment.
- MnDOT performs some counting at overpasses.
    - Need to figure out how to count people walking along rural shoulders
- Equipment Procurement
    - Use one vendor primarily because of data management capability and availability of large range of products
- QA/QC
    - Validate the data with manual counts from camera
    - Check for zeros or big spikes in the data
- TMG should include procedures on collecting pedestrian data along rural shoulders. There was some struggle with TMAS format. Also provide guidance on how to estimate adjustment factors and include more case studies on how people are using pedestrian data.

Steve Abeyta, Colorado Department of Transportation

- Mostly concentrate on bicycle traffic for counting purposes, but try and include pedestrian counts as much as possible.
- Archive all raw data.
- Traffic software also includes procedures for flagging nonmotorized data if anomalies are detected.
    - However, this functionality has not been evaluated yet
- Data sharing is important, when data is received from other jurisdictions, an identifier is added to the data to distinguish the source and is then uploaded to the central database.
- Equipment Procurement
    - Used grants to buy equipment initially
    - Have a sole source provider of the equipment

Kenneth Brubaker, Colorado Department of Transportation

- Struggling with the issue of how and where to monitor pedestrians.

  - Big question is whether to scatter resources everywhere or focus on project specific counts
- Technology is still a challenge for counting pedestrians.
- Perform 4 checks on data
  - Consecutive zeros
  - Data gaps
  - Use previous years data to calculate a mean value, if current value is greater than certain standard deviations above the mean, flag it
  - Directional distribution check – It varies from site to site but typically, if a site has a split greater than 70/30, it could indicate something is wrong
- Typically use pedestrian data to identify warrants for mid-block crossings.
- Site selection for counting at alternate locations such as overpasses and underpasses is important.
- TMG should provide guidance on site selection for continuous count locations. Also important to consider the overall question of where to count.

Dr. Tracy Hadden Loh, Rails-to-Trails Conservancy

- RTC has a national network of trail counters in urban areas.
- RTC has developed a cell phone app for manual counts called GoCounter
  - These counts can be screenline or intersection counts
  - App supports bicycle and pedestrian counts separately but simultaneously
  - Location and timestamp are recorded
  - Will release in November on both ios and Android platforms
  - Data will be available in both TMG as well as csv format
- Some manual counts are performed along overpasses and underpasses, some automated counting along a stairway. Keep security of devices in minds when counting at alternate locations, and check on the devices regularly.
- Typically do not share the data publicly, just share with the client. Not enough resources to share data with everyone.
- Every single data mechanism has major quality issues that are not necessarily predictable, hence multi part QA/QC is necessary.
- Check your equipment and perform regular maintenance. Investing in a satellite modem has allowed RTC to check counters more frequently.
- QA/QC checks
  - Malfunction, outliers
  - Big window of zeros

- Is data certain standard deviation’s outside the mean
- Currently do not have separate checks for low and high volume trails

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